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DEPARTMENT OF COMMERCE

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MINING METHODS, PRACTICES, AND COSTS OF THE CANANEA CONSOLIDATED COPPER CO., SONORA, MEXICO

BY

WILLIAM CATRON

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MINING METHODS, PRACTICES, AND COSTS OF THE CANANEA CONSOLIDATED COPPER CO., SONORA, MEXICO [1]

By William Catron [2]

INTRODUCTION

This paper is one of a series being prepared by the United States Bureau of Mines on mining methods, practices, and costs in the various mining districts of the United States. The mining methods described are those used in the mines of the Cananea Consolidated Copper Co., a Mexican corporation whose holding company in the United States is the Greene Cananea Copper Co.

The mines are at Cananea, Sonora, Mexico, 25 miles directly south of the international boundary, approximately in 31° north latitude and 110 to 130° west longitude. Cananea is connected with the boundary towns of Naco and Nogales, Ariz., by a standard-gage railroad.

The population of the Cananea district is approximately 15,000. The mines employ about 1,300 men underground and 300 on the surface, while the concentrator and smelter employ about 900 more. The current production of the three producing mines, the Colorado, Capote, and Veta Grande, is about 2,500 tons of ore per day, working on two 8-hour shifts.

From the beginning of operations by the present company in 1901 to the end of 1928, a total of 20,059,229 wet tons of ore has been mined, with a metal production of 1,032,147,402 pounds of copper, 22,754,573 ounces of silver, and 144,308 ounces of gold.

ACKNOWLEDGMENTS

The author is indebted to T. Evans, general manager of the Cananea Consolidated Copper Co., for permission to write this paper. He likewise wishes to acknowledge the assistance of the company staff and of C. H. Johnson, assistant mining engineer of the United States Bureau of Mines.

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1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6247."

2 - One of the consulting engineers, U. S. Bureau of Mines.

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HISTORY [3]

Little is known of the early Spanish workings. Francisco Velasco, writing of Sonora about 1845, states that the mines were worked before the eighteenth century by the House of Guea, and later by Jose Perez of Arizpe, the capital of the district. Finally, it is said that in 1865 General Ignacio Pesquiera, with an escort of 500 soldiers, established a camp at Ronquillo, where the present smelter is, and erected a small smelting plant at the place now known as Cananea Vieja. Mining and smelting were carried on in a desultory way for about 15 years. About 1881 a Cleveland company built a smelter at the foot of the hills some 10 miles west of the mines at Cajoncito. Ore averaging 20 per cent copper and 15 ounces of silver was smelted and operations carried on for about two years. The smelter was then moved to Puerticitos, but was abandoned after another year.

The properties around Cobre Grande at the southeast end of the Cananea Mountains were bonded to Charles Benham of New York, up to 1886, and later to Major Morton in the interest of F. Augustus Heinze. After taking out about $110,000 in copper matte, this bond was given up because of the death of Major Morton.

Colonel W. C. Greene then secured control of practically all the mining properties in the Cananea district. Failing to obtain private capital to develop them, he organized the Cananea Consolidated Copper Co., Mexican corporation, and later floated the stock of the Greene Consolidated Copper Co., the holding company, on the New York stock market. This subsequently was merged with the Greene Cananea Copper Co.

The first smelting furnace was blown in May, 1899; the first concentrator was built in 1901, and the narrow-gage railroad connecting this plant with the several mines of the district was completed in 1902.

The great Capote ore body was struck in May, 1900, and the Oversight in December of the same year. The Veta Grande and Chivatera ore bodies, also lying within the Capote basin, were opened at later dates, as were a number of outside mines, such as the Cananea-Duluth, the American, Kirk, Cobre Grande, Sierra de Cobre, Elisa, Henrietta, and Puerticitos. In 1926 the Colorado ore body was discovered.

Figure 1 is a map of the district.

GEOLOGY

The rocks of the central part of the Cananea district are largely of igneous origin. The oldest rocks, however, are limestone and quartzite, probably of Paleozoic age, of considerable thickness but small areal extent. These are overlaid by thick, undifferentiated volcanics. Both sedimentaries and volcanics are intimately intruded by acid and basic igneous rocks, from which the ore deposits have been derived.

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3 - Emmons, S. F., Cananea Mining District, Sonora, Mexico. Economic Geology, vol. 5, No. 4, June, 1910.

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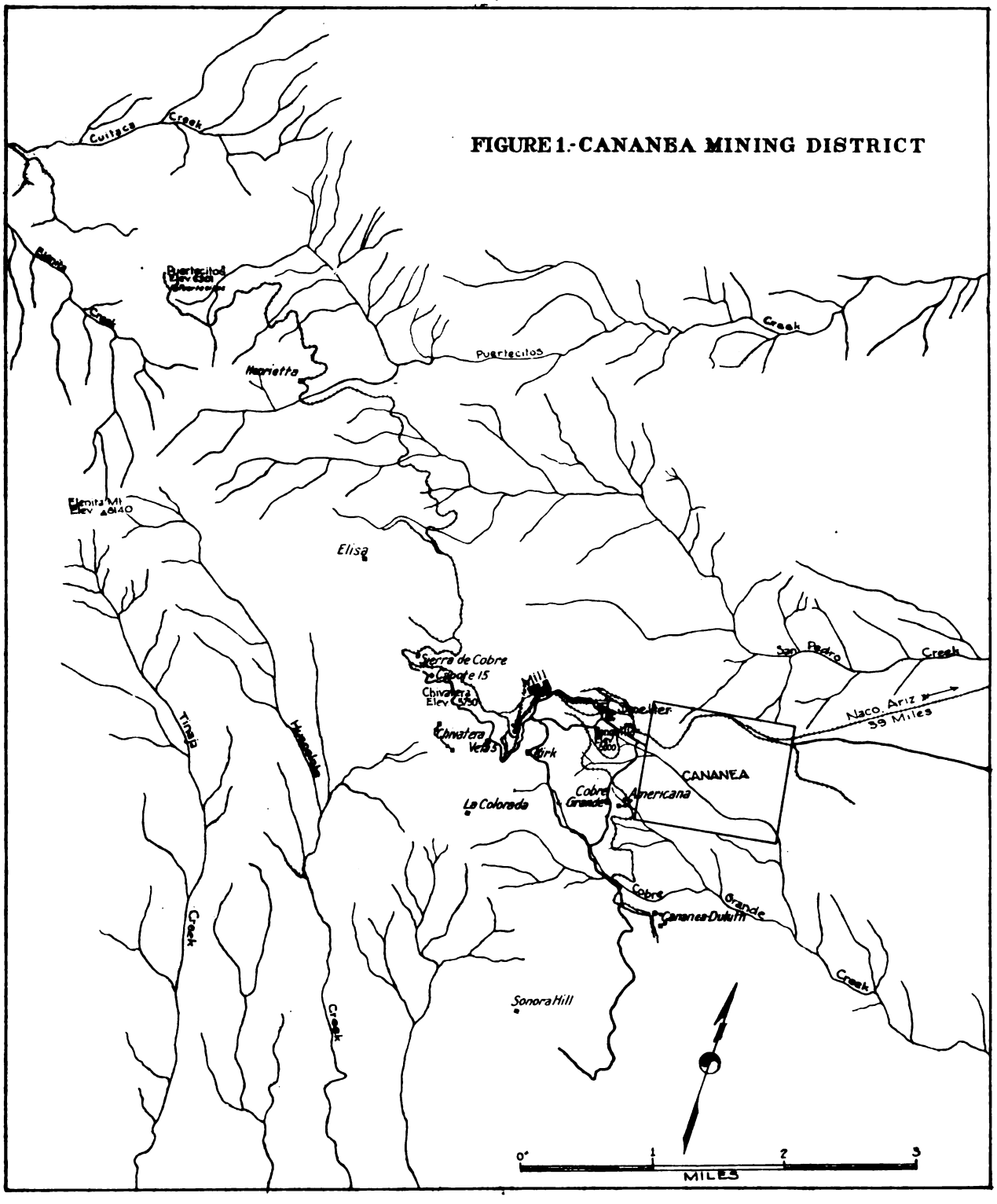

FIGURE 1.-CANANEA MINING DISTRICT

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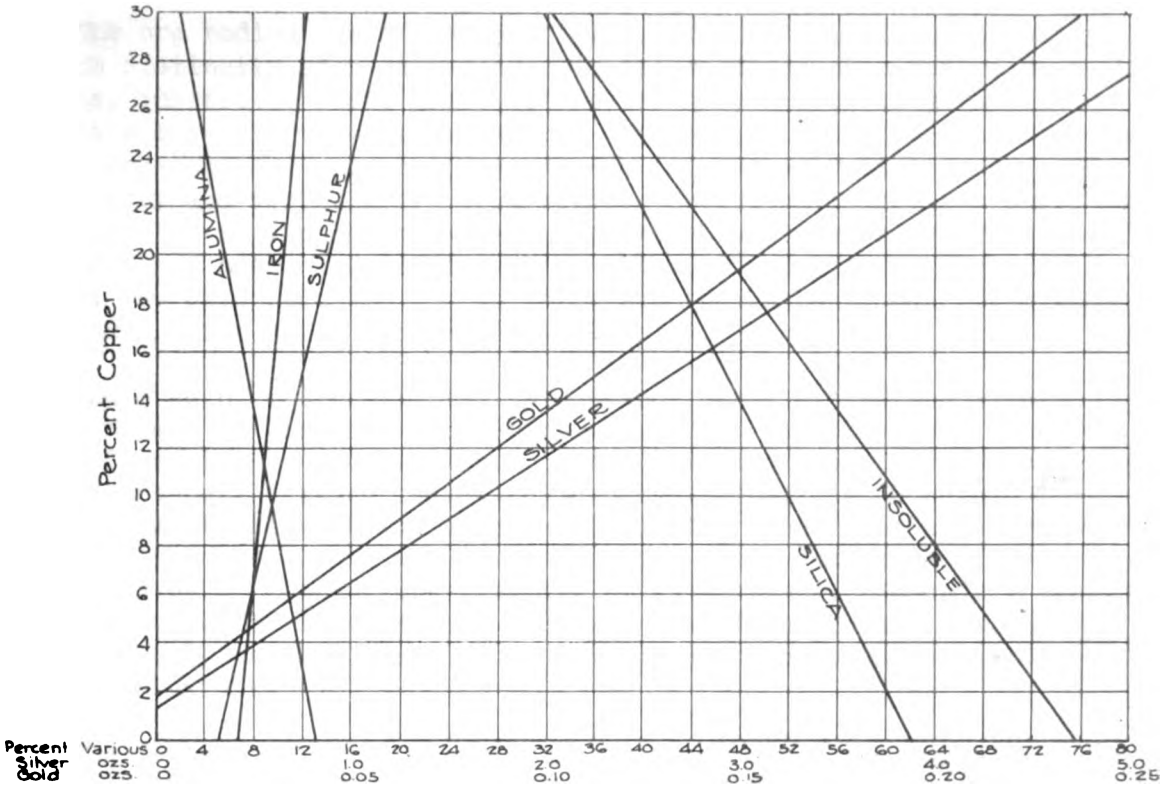
Percent Copper
ALUMINA
IRON
SULPHUR
GOLD
SILVER
SILICA
INSOLUBLE
Percent Various 0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80
Silver ozs. 0.0 1.0 2.0 3.0 4.0 5.0
Gold ozs. 0.0 0.05 0.10 0.15 0.20 0.25

FIGURE 2. — VARIATION OF VALUES AND ANALYSIS OF COLORADA ORE WITH COPPER CONTENT (BASED ON TOTAL RECEIPTS TO DATE: AUGUST, 1928

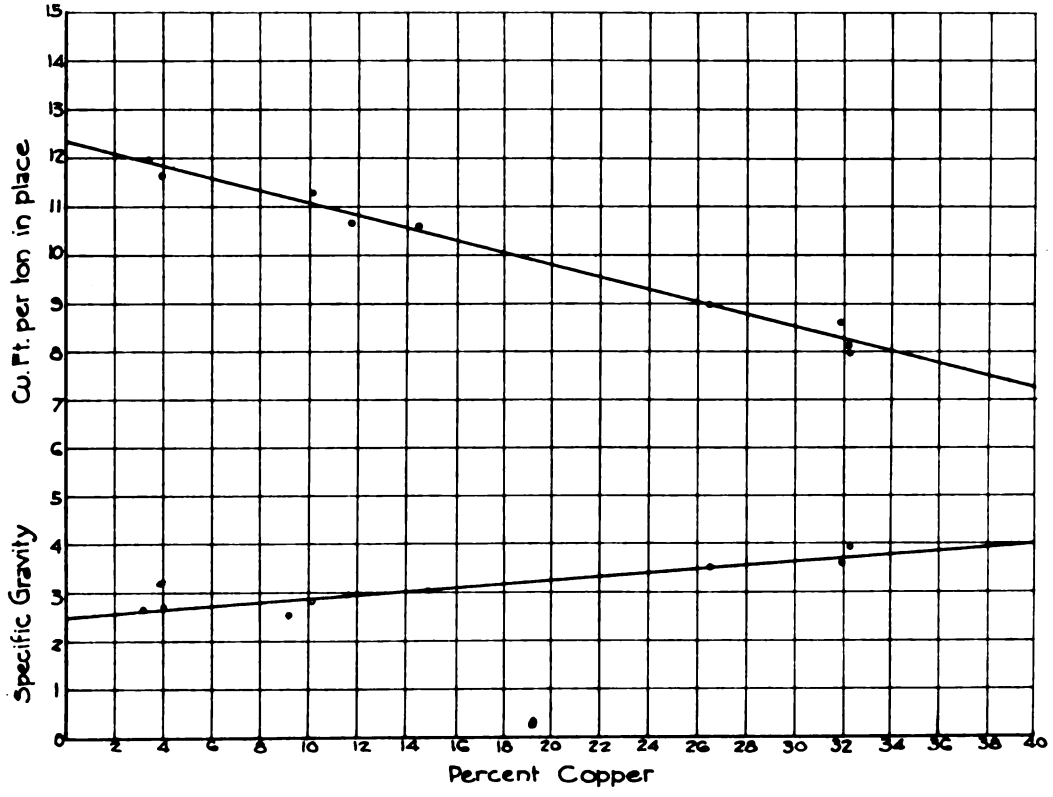

FIGURE 3. — LA COLORADA ORE. SPECIFIC GRAVITY AND CU. FT. PER TON IN PLACE. VARYING PERCENT OF COPPER

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The ore bodies are of various types, often difficult to classify, ranging from distinctly high temperature to intermediate temperature deposits in limestone, quartzite, tuff, granite, and porphyry. Ores in garnetized limestone have been of great importance in the past, though none is now being mined; they were chiefly primary ores, though of unusually high grade, and were very spotty and irregular in occurrence. Occasionally shallow enrichment produced small but very rich deposits. The ore shoots were steep-dipping, with irregular and often indefinite walls. Stope boundaries were generally assay walls; the wall rock was not uniform, and though hard, was often seamed with slips and joints which made mining difficult.

The ores of the Capote and Veta Grande mines are of the intermediate temperature type. In this case secondary enrichment has played an important part in the formation of economic ore. The ore bodies are of irregular outline and have no well-defined structural control. They lie 50 to 500 feet below the surface in altered and highly-fractured ground which caves readily. The primary sulphide minerals are pyrite, with a small admixture of chalcopyrite and in places of considerable amounts of zinc blende. Secondary enrichment is responsible for large shoots and chimneys of chalcocite ore. With depth, particularly in the Capote mine, primary chalcocite and bornite are important ore minerals.

The deeper primary ores occur as vertical pipe-like deposits. The upper levels of the Colorado pipe are characterized by a ring of ore surrounding a waste core. This ore ring converges until on the bottom levels the waste core disappears and the pipe becomes a solid elliptical ore area. The mineralization follows well-defined zones of brecciation which have approximately circular or elliptical outlines. However, the stope boundaries are always determined by sampling, as the copper minerals extend outward from the main ore body as a network of small veinlets and make low-grade ore of the wall rock adjacent to the pipe. Careful stope sampling is therefore necessary. The ore minerals of these deposits are chalcocite, bornite, chalcopyrite, tennantite, and tetradherite. In the Colorada, molybdenite is abundant and at another similar deposit, the Cananea-Duluth, both sphalerite and galena are common. Quartz is the principal gangue mineral. Figure 2 shows the composition of varying grades of Colorada ore.

PROSPECTING AND EXPLORATION

Prospecting and exploration at first consisted of sinking shafts or driving tunnels on mineralized outcrops or in the vicinity of the prominent iron-stained gossans which were considered indications of secondary enrichments below. Later, and continuing to the present time, a great deal of drilling has been done in the district. Prospect drilling of new areas from the surface has been done by churn drills; diamond drilling has been carried on underground, generally in exploring or developing known ore.

Churn Drilling

A considerable amount of churn drilling was done along the southwesterly extension of the Ricketts fault in an attempt to find a lateral extension of the Oversight ore. The Colorada and Sonora Hill areas were churn-

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drilled on coordinates in a systematic exploration campaign. Holes were drilled on the corners of 200-foot squares. At first, when interest was concentrated chiefly on possible secondary ores, holes were drilled to depths of only 300 to 500 feet. Later, upon discovering the existence of the rich primary ores, many holes were drilled to depths of 800 to 1,600 feet.

The holes did not need to be cased, except a few in soft ground, as in the Oversight area. The holes were sampled at 5-foot intervals, all the way from the surface. All the sludge was run through a splitter, saving a 1/4-part sample. This sample was dried, without settling or decanting, over a fire, and the sample assayed for total copper. Composite samples of 40 or 50 foot lengths were assayed for gold and silver. A geologist inspected the sludge and noted the kind and character of rock being drilled through.

Diamond Drilling

Diamond drilling has not been used in the past for primary surface prospecting. At the Elisa mine several holes were drilled to determine the geologic structure of an unprospected area. At the Capote vertical and inclined down holes were drilled from the bottom level to test the extent of the primary ore. In the Colorada mine a body of low-grade ore was developed by horizontal holes laid out on regular coordinates on two levels.

The bit used in diamond drilling gives a 1-1/2-inch hole and a 13/16-inch core. No casing has been used in the diamond-drill holes. Occasionally a hole is grouted to prevent loss of water. The sludge is run through a riffle-type sample-splitter which takes a one-eighth split. The sample is put in a compressed-air sample drier or filter, which removes most of the water. This filter was adopted after trying tubs and settling launders, which, it was thought, caused errors by losses during decanting or by concentration of the copper minerals in the baffles of the launders. The filter has the advantage of being sturdy and compact, and is easily and quickly operated. Since it may not hold all the sludge and water of the split sample from a given length of hole, it may be necessary to blow out the water two or three times to get a complete sample. Heavy canvas is used for the filtering element; the water comes through practically clear. The dried samples are weighed and assayed for total copper by the permanganate method.

The core is not removed at regular intervals, but is taken out whenever the core barrel is full or the rods are pulled for any other reason. Each section of core removed is handled as a unit. The percentage of the core recovered is noted each time any is removed from the hole. The core is carefully inspected every day by a geologist, and notes are taken for permanent record. A small piece of core is taken for a permanent sample and the remainder is sent to the assay office where it is ground, weighed, and assayed for total copper by the permanganate method. If gold and silver assays are desired, they may be run on composite samples of the entire hole or certain portions of it, or on individual cores. Chief reliance for knowledge of the value of the ground drilled is placed upon the core assays; the sludge serves as a check. If a combined value is desired, it may be calculated either according to relative weights of core and sludge or according to percentage recoveries and volumes.

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Core recoveries vary greatly in the district. In the Colorada mine recoveries have ranged from 40 to 95 per cent, averaging 75 per cent; in the Elisa mine, in hard limestone, recoveries averaged more than that figure, while in the soft Capote ground they were generally under 50 per cent.

"Long-Hole" Drilling

A great many prospect holes have been drilled in the Elisa and Colorada mines with a heavy drifter-type machine. Its principal application has been the delimiting of ore bodies, serving the purpose of crosscuts through the veins, thus assisting in the laying out of development work. The holes have all been flat and have varied in length from 35 to 125 feet, averaging 85 feet.

The drill is similar to a drifter except that it has a swiveled water connection ahead of the drill chuck. A 1-1/2-inch shank back of the swivel fits the machine chuck; the front end of the swivel receives the threaded shank of the 1-1/4-inch drill steel. The shank of the swivel connection is retempered after each hole. Mine water is always available under sufficient head and no pump is used. The drill is set on a cross arm between two columns. One and one-quarter inch hollow-round steel is used in 6-foot lengths with a few 3-foot lengths for making changes. The steel is connected by sleeve joints. The bits are formed on 3-foot lengths of steel; the starter bit is 3 inches in diameter and the succeeding bits decrease in size by one-sixteenth inch. The sludge is all saved, settled in tubs, and the water decanted. The drill crew consists of two men. Twelve holes, totaling 1,180 feet, were drilled in 64 shifts, including the time required to move and set up, or an average of 18-1/2 feet per shift.

SAMPLING AND ESTIMATION

Drifts and crosscuts are pick-sampled at 5-foot intervals when in waste. When there is doubt whether it is waste or low-grade ore, channel samples are taken. These are cut horizontally, sometimes with a moil and hammer, but usually with a compressed-air chipping hammer. Grab or pick samples are taken from the face only for current information. Pick samples for permanent records are taken from the raises. Samples for control of stoping are taken by a crew which works on a special shift, overlapping both day and night shifts. Assay results from these samples are painted on the timber or the rock wall of the stope on the day following the taking of the sample. This prevents mining waste or leaving good ore, as it is often impossible, especially in the Colorada, to distinguish between ore and waste. When stopes are finished or before fill is run into a mined-out floor, another crew taken pick samples along the walls for permanent record on the assay maps.

Mined ore is sampled before being dumped into pockets or bins at the shaft. At the Capote, for example, a grab sample is taken from each car as it reaches the shaft station. At the Colorada, motor cars of ore are sampled before being dumped into the pockets at the shaft. The 1-ton cars hoisted in cages to the 450 level are sampled there. Small pieces of wood are marked with the stope numbers and placed on the cars before they are caged to show the

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source of the ore. The car samples, as well as the pick and channel samples from stopes and development work, are sent each day to the sample mill at the Capote mine. There they are crushed, dried, ground, and split, and the resulting small samples are sent to the assay office at Ronquillo. All mine samples are assayed by the permanganate method. By means of the methods of sampling in use, the number of cars and the tonnage and grade produced by each stope and by the mine is known for each day. These figures check the returns from the mill and smelter sample plants closely enough for purposes of control of production.

Methods of estimating reserves vary according to the data available. In the caving blocks the ore outline is laid out on the assay map of the level or the undercut floor to include all ore possible that runs above shipping grade and exclude any that is under. All assays within the ore outline are then averaged to give an average grade; the area is computed or measured. Products of areas by grades on the level in question and the one above are then combined to give an average area and grade, and multiplied by the height to give cubic feet.

Information gathered from all previous stoping or development assays was used in making estimates of ore in blocks laid out for cut-and-fill or other methods. Either vertical or horizontal end areas may be calculated. For the initial stopes on a level, drifts and crosscuts are usually the only sources of information available. Allowance must be made for the position of the drifts, if the ore is in the shape of a vein with a high-grade core and low-grade walls. High assays may or may not be scaled down, depending upon the nature of the ore. Pillars can be estimated with considerable accuracy, as usually there are assays on both sidesand at every floor.

The conversion of cubic feet to tons was formerly calculated so as to allow for sorting. In the Capote, for example, 15 cubic feet per ton was at one time the factor used. Figure 3 is a chart which shows the relation between grade and cubic feet per ton of Colorada ore and which is used in making conversions from cubic feet to tons.

METHODS OF DEVELOPMENT AND MINING

Development

General Development. - Because of the hilly nature of the country, the mines of this district usually have been developed by both shafts and tunnels. The Veta Grande is worked through a vertical shaft and a tunnel, and has underground connection with other mines. The Capote is at present operated through a 5-compartment vertical shaft, with underground connections to the Elisa and other mines. A former operating shaft and adits on the upper levels of the Capote are now abandoned, or serve only for ventilation. The Colorada is opened by a vertical shaft from the surface, with two adits on the 500 level (see fig. 4). On this level ore is hauled from the shaft to the railroad ore bins, waste for fill and mine timber and supplies are taken in, and the men travel from change house to shaft. Main tunnels or adits are generally driven 8 by 8 feet in the clear, and drifts in which tramming is

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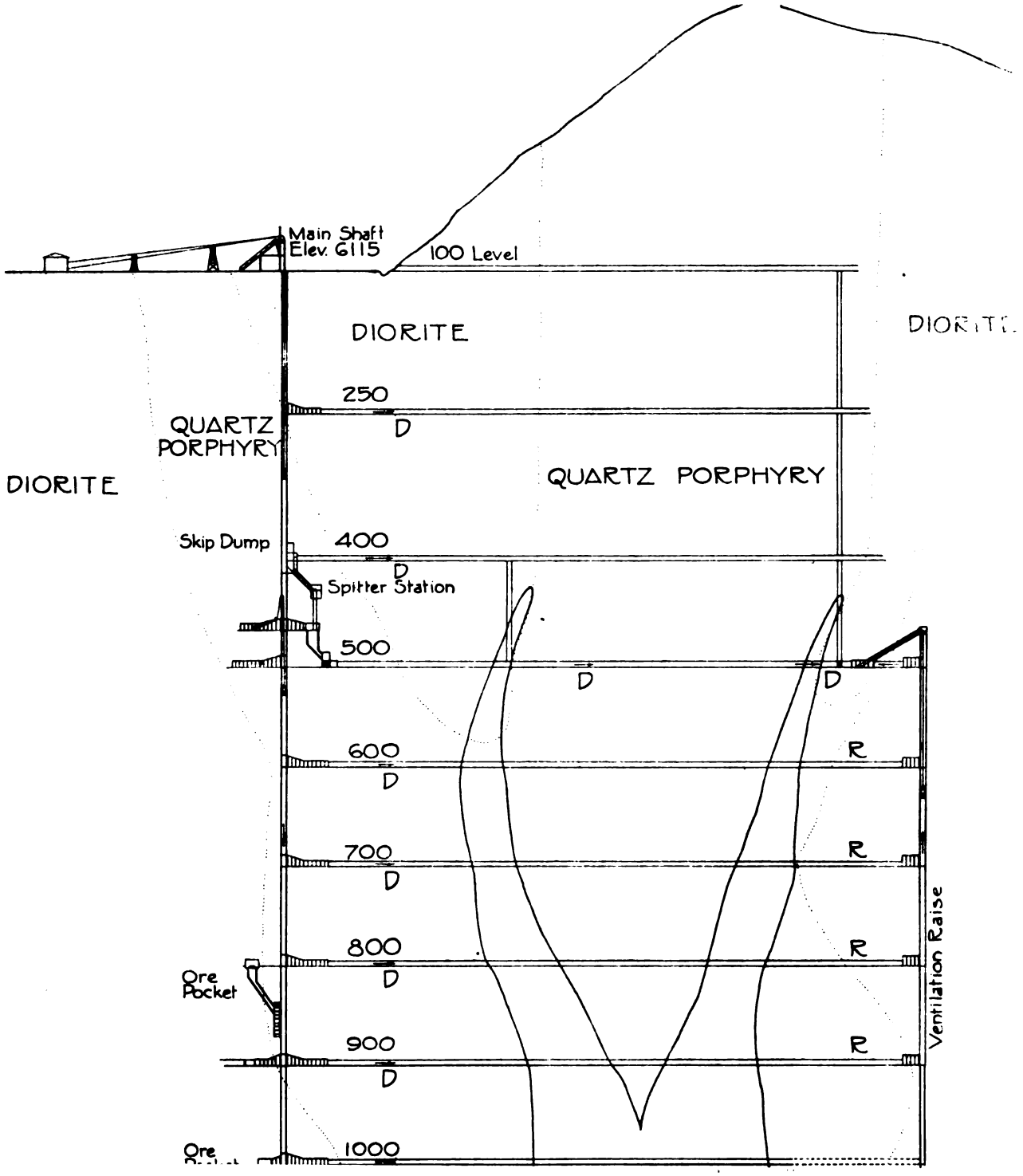

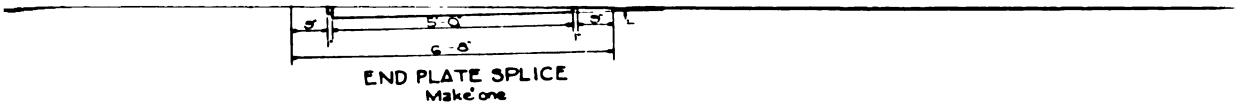

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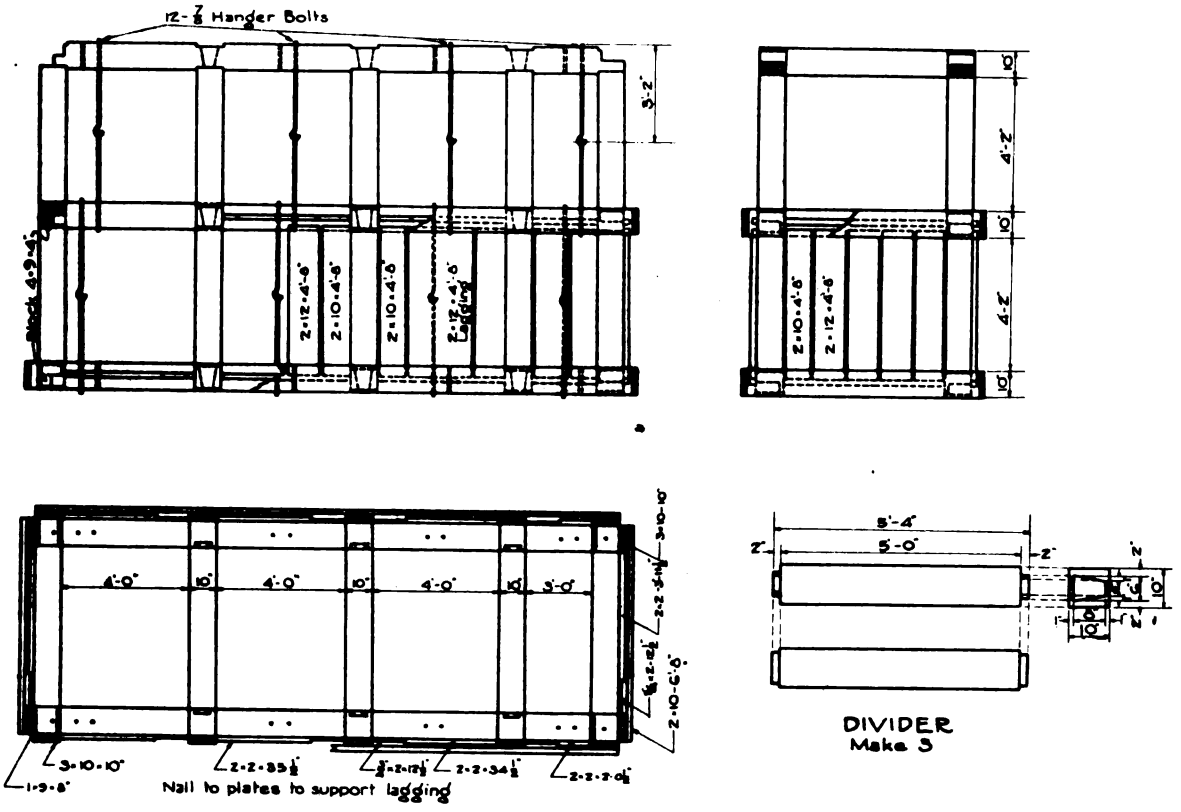

FIGURE 5. - 3½ COMPARTMENT SHAFT TIMBERING PROVIDING FOR ENLARGEMENT

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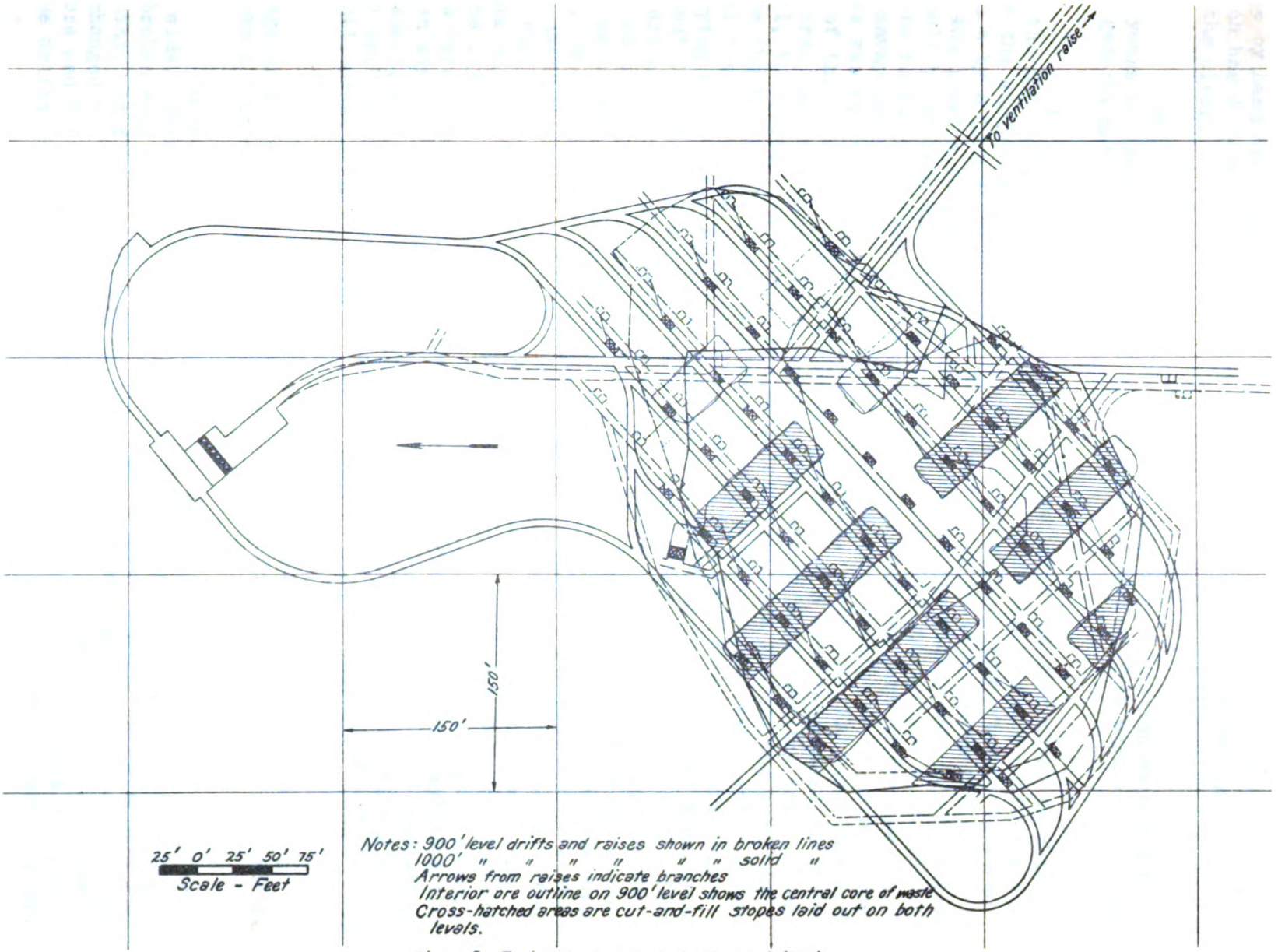
To ventilation raise
150'
150'
25' 0' 25' 50' 75'
Scale - Feet
Notes: 900' level drifts and raises shown in broken lines
1000' " " " " " " solid "
Arrows from raises indicate branches
Interior ore outline on 900' level shows the central core of waste.
Cross-hatched areas are cut-and-fill stopes laid out on both levels.

Figure 6.- Typical haulage and development levels

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done by hand are 6 by 8 feet. All shafts, with the exception of the Veta, which has 4 by 4-1/2 foot compartments, have hoisting compartments 4 by 5 feet in the clear.

The opening of the Colorada ore body for production required about two years of intensive work. The following account of this work will illustrate the general methods of development:

In July, 1926, a drift was started from the Kirk mine, on what is now the 500 level of the Colorada. A month later the Colorada shaft was started. From the surface to the 300 level the shaft was three-compartment, timbered with 8 by 8 inch timber. Below this point 10 by 10 inch timber was used. At the 450 level a fourth compartment was added at the manway end. On this level a small hoist room was cut out and a hoist installed to operate a sinking cage in the third compartment. The counterbalance occupied part of the new fourth or manway compartment. A pocket for handling rock brought up in cars on the cages was built between the 500 and 450 levels. Below the 500 level the sinking of the shaft was paralleled by the sinking of a two-compartment winze in the ore. As soon as possible, connections were made between the two on each level, to provide ventilation and additional entrance for men and supplies. Below the 500 level, the levels were spaced uniformly 125 feet apart. At each level the shaft crew cut a station about 20 feet back from the shaft before carrying the sinking further. This allowed drifting to be started when desired without interrupting work in the shaft. During the two-year period, the four-compartment shaft was carried to the 1,100 level, and two skip compartments were added from the surface to the 900 level. The latter was done by raising from each level to the one above, several such lifts being worked at the same time. When sinking, wall plates framed with half-length tenons on one end were used; the spaces left by the short tenons were filled with blocks. Then, when raising and timbering the skip compartments it was easy to remove the blocks and fit the new wall plates into position. Figure 5 shows the timbering of the initial three and one-half compartments. At the time the skip compartments were being driven, the present steel headframe was built, replacing the wooden sinking headframe without interruption to operations. Upon completing the shaft, a pocket was cut on the 800 level. This was done by driving a small inclined raise from the shaft to the level, afterward enlarging the raise to full pocket size.

As rapidly as possible each level was explored by drifting, and haulage drifts were laid out according to the information thus gained. Figure 6 shows a typical haulage level.

On the 500 level the main drifts were driven 8 feet high and 8 or 9 feet wide. Work was carried on in three shifts per day; drilling was done over the broken rock pile from horizontal bars. Trolley locomotives were used for tramming. At first 2-ton cars on 18-inch track were used; afterward the gage was changed to 36 inches on this level, and 7-ton bottom-dump cars were used for ore and 5-ton rocker-dump cars for hauling waste fill. At that time, some of the drifts were widened. The main adit is now 8 by 10 feet in most places.

Below the 500 level some of the main drifts from the shaft to the ore body were likewise driven with all possible speed. Drilling was done over

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the muck pile, and four muckers employed at each face. Only 1-ton cars and hand-tramming have been used for development work on these levels. Sometimes the drifts were double-tracked as advanced, to give a good supply of empty cars at the face. On the 800 level, which is the haulage level for all stopes between it and the 500 level, the 1-ton cars have been replaced by 4-ton gable bottom cars and electric haulage has been installed. Track gage, however, has been kept at 18 inches. Most of the drifting, even through the ore, was done without timbering. When drifts are timbered, as in places under the stopes, square-set timber with a 6-foot cap is used, making the drift about 5 by 8 feet in the clear. This is large enough for either the 1 or the 4 ton cars.

Raises were driven from level to level in accordance with stoping plans. These raises were of three kinds: Square-set, cribbed, and stulled (figs. 7 and 8).

On the side of the ore body opposite to the Colorada shaft a large 3-compartment shaft was put up from the 800 to the 500 level. This was intended primarily for ventilation and an emergency exit. One compartment is a manway, however, and cages have been installed in the other two, with a hoist on the 500 level. The shaft thus serves for an emergency exit and for handling men and supplies.

By July, 1928, when regular production started in the Colorada, approximately 1,500 feet of shaft and 900 feet of winze had been sunk and 3,900 feet of raises and 36,000 feet of drifts had been run. In July and August five stopes came into production, one shrinkage stope above the 500 level, a square-set and a cut-and-fill (rill) above the 600 level, and two cut-and-fills above the 700 level.

Since that time development and stoping have gone on together. The 1,000 and 1,200 levels will be motor-haulage levels; the former is now nearly completed. It should be borne in mind, when inspecting the cost tables at the end of this paper, that development has advanced faster than mining. It is estimated that the average cost per ton for development, over the life of the ore body as now calculated, will be less than half the present figure.

Shaft-Sinking. - Cananea shaft-sinking practice is well illustrated by the work in the Colorada shaft from the middle of 1926 to the end of 1929.

With two or three rounds broken at the surface, the collar set was placed and a standard wooden sinking headframe erected. A compressed-air hoist was used at first to operate the sinking cage but was soon succeeded by a 112-hp. electric double-drum hoist and then by the cage hoist now in use. In addition, when the shaft reached the 500 level, a hoist room was cut on the 450 level, and another 112-hp. electric hoist was installed to handle the sinking operations and release the surface hoist for other service.

Figure 9 shows the round used in the 4-compartment section of the shaft, below the 500 level. Six 65-pound sinking drills and 1-inch hollow-round steel were used for drilling. Drill steel is the same for all mining operations as regards bits and lengths. The common form of cross bit having a 5

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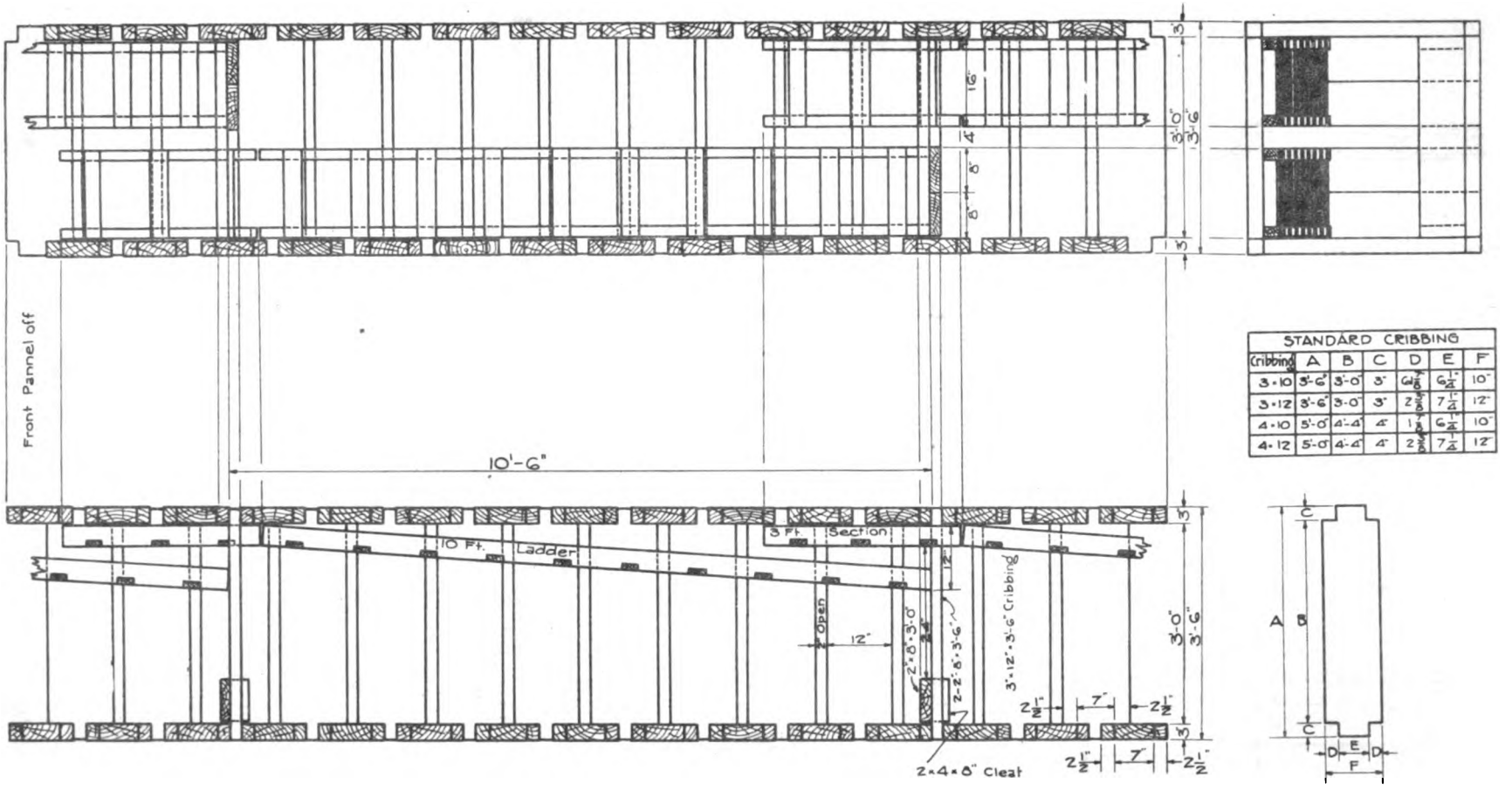

STANDARD CRIBBING

Cribbing	A	B	C	D	E	F
3·10	3'-6"	3'-0"	3"	6⅛"	6¼"	10"
3·12	3'-6"	3'-0"	3"	2	7¼"	12"
4·10	5'-0"	4'-4"	4"	1⅝	6¼"	10"
4·12	5'-0"	4'-4"	4"	2⅝	7¼"	12"

FIGURE 7. – STANDARD CRIBBING AND STANDARD 3'×3' SAFETY MANWAY

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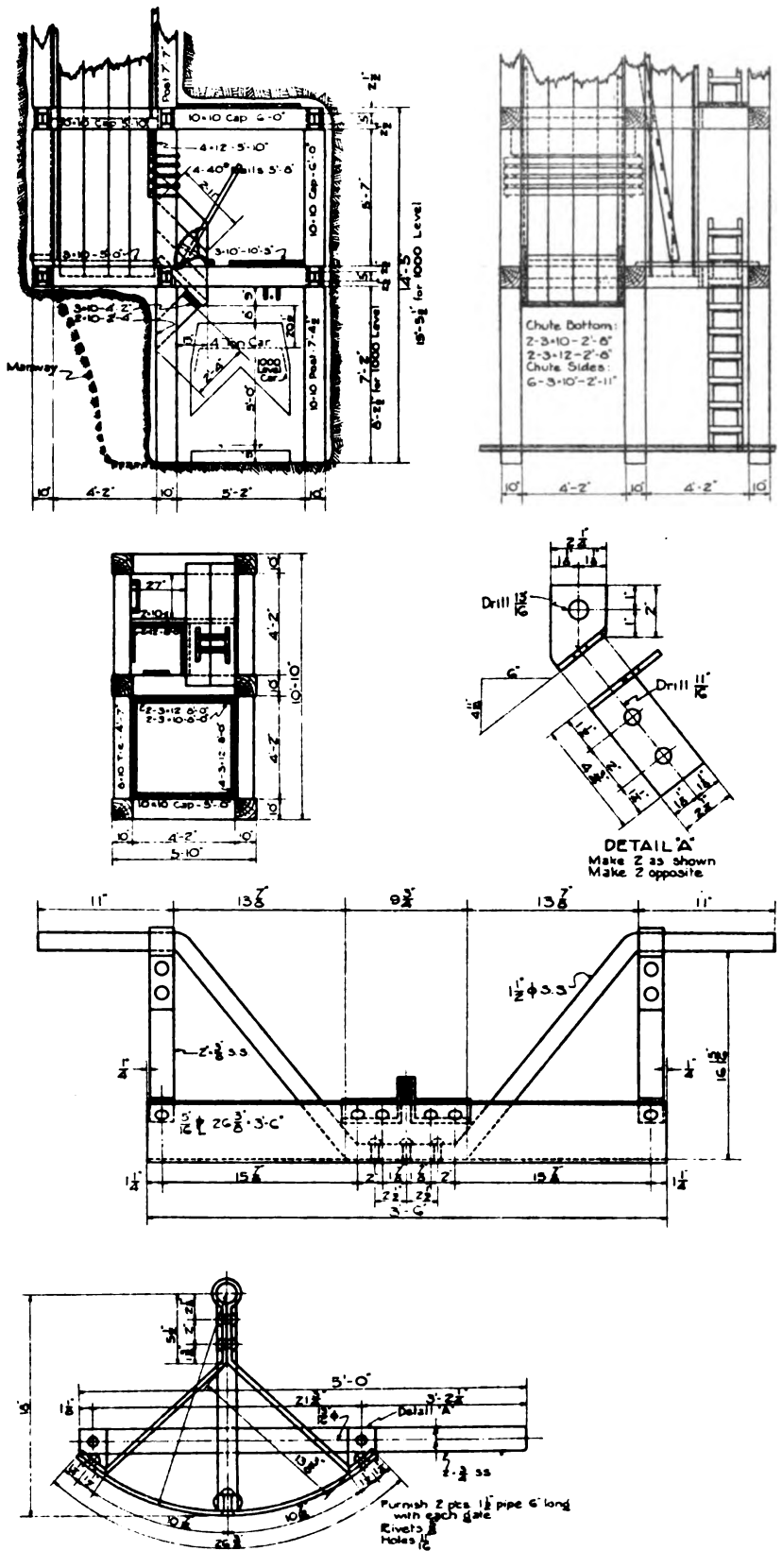

FIGURE 8. - STANDARD SQUARE SET RAISE AND CHUTE 800 LEVEL, "LA COLORADA" MINE

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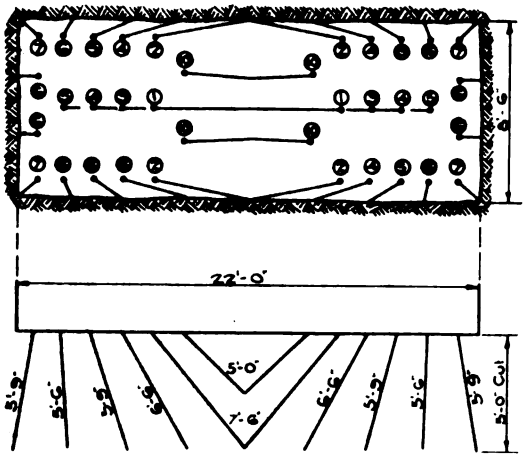

FIGURE 9.- FOUR COMPARTMENT SHAFT. ROUND

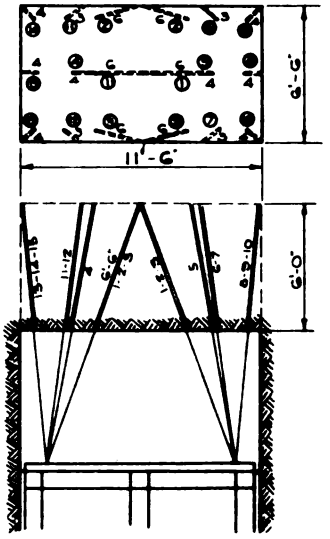

FIGURE 10. - STANDARD RAISE ROUND

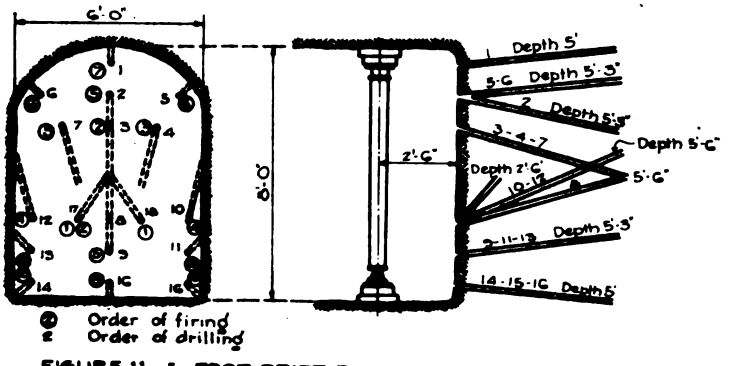

FIGURE 11.- 5-FOOT DRIFT ROUND FOR HARD GROUND

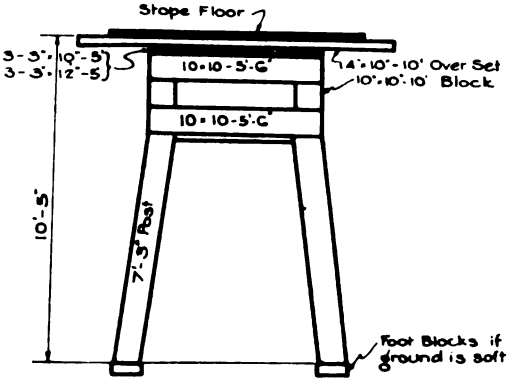

FIGURE 12.-SECTION THRU DRIFT OR CROSSCUT

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and 15° double taper is used. Starter bits are 2 inches in diameter; the following bits decrease by one-sixteenth inch in gage. Starters are 2 feet 9 inches long and succeeding pieces are each 18 inches longer. All steel is hollow, and no dry drilling is allowed underground. Electric blasting with delay action detonators was used throughout the sinking of this shaft. Above the 600 level the usual Cananea practice of shoveling the rock broken by the blasts into a 1-ton car was followed, except for a short period when a sinking bucket was used. The bucket was dumped over a slide into 2-ton motor cars on the 500-level station. A special light single-deck cage, with extension guides permitting the cage to be lowered onto the bottom, is used for mucking into cars in shaft sinking. The rock is shoveled directly into the car through the open sides of the cage.

The publication of an article describing a shaft-sinking device used at the Elm Orlu mine at Butte[4] led to the adoption of an auxiliary mucking skip --a shallow steel box, open on top and at one end, hung by a bail which allowed it to be easily dumped. This was hoisted by a single-drum air hoist placed on I-beams in one of the center compartments. The skip, which held one carload, was lowered onto the muck pile and filled; the cage and car were then dropped to the bottom, the skip was hoisted a few feet, and the muck was dumped into the car. The advantage of the skip is that it can be placed to best advantage, as, for example, when the blast throws most of the rock to one end of the shaft. It is so low that it is much easier to shovel into it than into the car or a bucket. Finally, it never leaves the bottom, so that no delay occurs while the rock is being hoisted. Its introduction gave an increase of 20 per cent in sinking speed. A maximum of 107 tons was mucked out in seven hours, and never over 12 hours was needed to clean out the usual 6-foot round.

The Colorada shaft timber set has already been shown (fig. 5). An interesting detail is the use of a bridge piece outside the wall and end plates to hold the lagging in place. This is put in place on the timber before it leaves the framing shed. Lagging is placed very rapidly and needs no blocking or nailing. When once in, it can be removed only by being cut out. To use the bridge piece the shaft need be made only slightly larger.

No fixed cycle of operations was followed. If a crew came on shift and found the shaft mucked out and timbered, they would drill and blast in four hours and spend the rest of the shift mucking. The following shift would at least finish mucking. The third shift, if the ground would stand without timbering, as was often the case, would drill and blast again. When it was possible to hang and block two sets in one shift, this was done.

The shaft crew consisted of eight men, including a jigger boss, in the shaft, one top lander, and one hoist engineer. The direct sinking cost for four compartments from the 500 to below the 1,300 level, a distance of 1,027 feet, was as follows: Labor, $43.46; supplies, $27.26; power, $2.44; sundries, $1.02; total $74.18. This does not include stations, pockets, preparatory work, or hoist installations.

4 - Drullard, H. R., Shaft Sinking To-day at Butte. Eng. and Min. Jour., vol. 123, Feb. 26, 1927, p. 357.

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In 1925 the Capote five-compartment shaft was deepened from the 1,400 to the 1,600 level, a total distance of 212 feet. The sinking cage and car were used in this work. The crew consisted of six shaftmen, one hoist engineer, one pumpman, and a boss. Careful and detailed costs were kept on this work, of which Table 1 is a summary.

Table 1. - Cost of sinking Capote shaft from 1,400 to 1,600 level

July to October, 1925,
Footage, 212 feet.

Preparations for sinking shaft	Shifts	Amount	Total	Per foot
Shaft and 1,400 level station:				
Labor	194-1/2	$542.12		
Supplies	-	302.87		
			$844.99	-
Hoist repairs and installation:				
Labor	72	205.70		
Supplies	-	198.41		
			404.11	-
Air-pump repairs:				
Labor	6-1/2	20.63		
Supplies	-	38.96		
			59.59	-
Pipe lines:				
Labor	34-1/2	92.20		
Supplies	-	346.61		
			438.81	-
Sinking-cage repairs:				
Labor	11	33.00		
Supplies	-	8.95		
			41.95	-
Hoist operation:				
Labor	18-1/2	48.50		
			48.50	-
Miscellaneous:				
Labor	2	3.75		
Supplies	-	12.48		
			16.23	-
Sundries:				
Shops and planing mill	-	220.04		
			220.04	-
Total preparatory work	339	-	$2,074.23	9.80

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Table 1. - Cost of sinking Capote shaft from 1,400 to 1,600 lever--Continued

Sinking shaft:	Shifts	Amount	Total	Per foot
Direct sinking:				
Labor: Shaftmen	1572-1/4	$6,289.00		29.73
Hoistmen	274	858.00		4.05
Pumpmen	266	1,064.00		5.03
Bosses	267	1,959.68		9.26
Bonus	-	1,116.95		5.28
			$11,287.63	53.36
Explosives and carbide:				
410 sticks 7/8" powder	-	20.30		0.09
9,354 sticks 1-1/8" powder (106 sticks per 50-lb. box)	-	746.71		3.53
1,765 delay detonators	-	315.43		1.49
1,375 pounds carbide	-	82.45		0.38
			1,164.98	5.50
Gum clothes	-	485.23		
			485.23	2.29
Supplies	-	71.38		
			71.38	0.33
			13,009.22	61.50
Hanger bolts:				
Labor	23-1/2	45.75		0.21
Supplies	-	245.69		1.16
			291.44	1.37
New drills, steel, and hose:				
Supplies	-	1,688.21		-
			1,688.21	7.98
New tools:				
Labor	12	33.65		0.15
Supplies	-	165.76		0.78
			199.41	0.94
Hoist repairs:				
Labor	11-3/4	39.37		0.18
Supplies	-	20.38		0.09
			59.75	0.27
Air-pump repairs:				
Labor	24-1/2	83.37		0.39
Supplies	-	199.37		0.94
			282.74	1.33

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Table 1. - Cost of sinking Capote shaft from 1,400 to 1,600 level -- Continued

Sinking shaft:	Shifts	Amount	Total	Per foot
Pipe lines:				
Labor	32	90.14		0.42
Supplies	-	892.60		4.22
			982.74	4.64
Drill repairs:				
Labor	6-1/2	18.75		0.08
Supplies	-	213.30		1.00
			232.05	1.08
Shaft doors:				
Labor	9	25.87		0.12
Supplies	-	18.70		0.08
			44.57	0.20
Blasting switch and lights:				
Labor	8-1/2	24.50		0.11
Supplies	-	26.79		0.12
			51.29	0.23
Tool and drill sharpening:				
Labor	48	117.54	-	0.55
Lowering sinking pump:				
Labor	20	59.37	-	0.28
Timber framing and material:				
Labor	385	955.84		4.51
Timber: Sets, 69,269 bd. ft.		1,901.31		8.98
Lagging, 16,330 bd. ft.		564.53		2.66
Bulkheads, 5,964 bd. ft.		198.12		0.93
Miscellaneous (ladders, guides, blocks, wedges, etc.)		243.47		1.15
Nails		101.89		0.48
Tools		6.18		0.02
			3,971.34	18.77
Framing 10 sets at Ronquillo framing shed:				
Labor	64	207.37		0.98
Supplies (tools, nails, bolts, timber)		1,417.59		6.70
			1,624.96	7.68
Air and power:				
Air for drills, 820 machine hours		324.28		
Air for pumps, 961 pump hours		378.57		
Power for hoist, 18,952 kw. h.		308.35		
			1,011.20	4.78

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Table 1. - Cost of sinking Oboote shaft from 1,400 to 1,600 level--Continued

Sinking Shaft:	Shifts	Amount	Total	Per foot
Sundries:				
Shops and planing mill	-	303.84	-	1.43
Total sinking	3,013-1/2	-	23,929.67	113.14
Total preparing to sink ..	339	-	2,074.23	9.80
Grand total	3,352-1/2	-	26,003.90	122.94

Statistics

Shaft section (4 compartments 4'0" by 5'0", 1 compartment 5'2" by 5'0"	28.0 by 8.5 feet
Footage	212 feet
Days sinking (3 shifts each)	87
Average footage per day	2.43
Rounds drilled	43
Depth per round	4.93
Holes per round	40
Sticks of 1-1/8-inch gelatin per round	223
Pounds powder per round	105.42
1-ton cars (20 cu.ft.) hoisted	5,022
Tons per foot	23.7

Shaft Repair. - The Cananea-Duluth mine had been idle for eight years when preparations for reopening it were started in January, 1929. The mine was flooded to above the 300 level, and the timber in the main or No. 3 shaft from the surface to the 600 level was rotted so that it had to be replaced. In addition, the same section of the shaft had only three compartments and was to be enlarged to four.

Previous experience had shown that pumps were unsatisfactory for removing the strongly acid water. Therefore a wooden headframe was erected over the old No. 2 shaft, a double-drum, 112-hp., electric hoist was set up, and 450-gallon bailing skips were installed in the shaft. Using only 400 gallons as the skip capacity, to allow for spillage, the power consumption for the first month, when the water was being hoisted an average distance of 335 feet, was 2.5 kw. h. per 1,000 gallons. During the next two months the bailers handled 300,000 to 400,000 gallons per day. In the second month, when the average distance hoisted was 440 feet, the average amount bailed was 278 gallons per minute. The corresponding figures for the third month were 500 feet and 256 gallons per minute. Extending the guides and repairing the shaft and equipment caused a delay of four to five hours each day. At a little over 500 feet, the load on the hoists was reduced by cutting a hole in the bailer and changing its capacity to 320 gallons.

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The first step toward retimbering the No. 3 shaft was to build a concrete collar. The old timber was torn out for 20 feet below the surface, and the extra compartment was taken out for about 30 feet down. The latter work had to be done by hand-drilling, as the compressor was not yet in operation. At a depth of 20 feet a hitch was cut all around the shaft, 2 feet deep, 2 feet high at the back and 4 feet high at the front. Temporary bearers were placed below it, forms built, and a concrete collar was poured.

Air was now available and the work of enlarging and retimbering the shaft was started. The round for the extra compartment consisted of seven vertical 6-foot holes blasted with four sticks each of 40 per cent gelatin and with fuse and caps. Two heavy sinking drills were used, and about an hour was usually needed to drill, load, and blast the round. After blasting, the old timber set was taken out. Any pieces that could be handled easily were hoisted to the surface, and the rest was allowed to fall to the 100 level. This resulted in frequent jams in the shaft, which were usually removed by blasting from below. A bulkhead had been built on the 100 level. All rock from the new compartment, as well as the old timber, fell to this level. The rock was trammed to old stopes and dumped for fill. The amount of old timber falling down made it impossible to use a chute, and all rock had to be shoveled by hand into the cars. As work progressed, the bulkhead was moved from level to level, so that it was never more than 100 feet below the new timber. Entrance from the surface to these levels was by way of a series of raises.

At first the working platform for the retimbering was simply laid on top of the old timber. A point was soon reached, however, where the old timber was too weak even to support the platform and often fell out for 40 or 50 feet below. Then a platform was made by hanging 20-foot 8 by 8 inch stringers below the last set and laying a floor of 3 by 10 inch plank on them. The 8 by 8's were hung on 3/8-inch iron chains 18 feet long with grabhooks at both ends. The chains passed around the corner posts, outside the bridging of the wall plates, and down to the platform stringers. Thus, the chains were out of the way of the set to be put in. The platform was lowered by ropes a set at a time as needed. When blasting, the end of the platform over the blast was raised a few feet and the planks were removed or piled at the far end. Men going down on the bench of the new compartment to drill always were safety belts.

As when sinking the Colorada and other shafts in the district, the timber sets were framed and completely assembled at the framing shed, checked over, numbered on each piece, and the joints lettered before the set was sent to the mine. This prevented misfits and simplified the delivery of the proper pieces to the shaft bottom. As it was often necessary to timber closely on account of the blocky nature of the volcanic tuff in which the shaft is sunk, and as there was usually not enough room below the new timber to swing a wall plate into place, the practice was followed of temporarily leaving out one divider on the bottom set. The wall plates were left unblocked opposite that piece. When the set below was in place, a screw jack was used to spring the wall plates apart far enough to drop the divider into place.

From the bottom to 40 feet above the 600 level the shaft was already divided into four-compartments and the timber was in good condition. To avoid

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damaging this part of the shaft, after the 500 level was passed, three compartments were bulkheaded over 40 feet above the 600 level, leaving open only the one next the fourth compartment. This open compartment was lined to form a chute so as to allow rock to drop to the 600 level without damage to the shaft.

When the water level was reached the work was interrupted. Bailers were then installed in the shaft and operated until the water was down to the 800 level, since which time the bailers in No. 2 shaft have been run a few hours a day to keep the mine dry. Bailing in No. 3 shaft presented difficulties due to the presence of old timber and partly broken sets which prevented the bailing skips from being lowered under water. Heavy tongs similar to ice tongs proved useful for grappling and pulling out submerged timbers. The bailers required extension guides into the water, and often the stumps of the old guide lag screws prevented the proper placing of regular wooden guides for this purpose. Skeleton guides were made of long pieces of strap iron bent double and held by two or three cross pieces. The free ends were lapped onto a short length of wooden guide which was drilled to be bolted onto the dividers. These guides were moved down from set to set, and as they were open front and back the old lag screws did not interfere with their placing.

Enlarging and retimbering were resumed on August 2 and finished to 40 feet above the 600 on August 25.

From February 22 to April 26, 453 feet of shaft, including four stations, was enlarged and retimbered, averaging 7.1 feet per day. From August 3 to August 22, 158 feet was completed, averaging 7.9 feet per day. Very commonly two sets and often three sets were put in in a day.

The shaft crew consisted of five shaft men and a jigger boss, three muckers below, a top lander, a hoist engineer, a compressor man on three shifts, and a foreman on one shift. During the entire difficult and dangerous job, not one man received a serious injury.

Drifting. - All drilling in drifts is done with Leyner-type machines mounted on 3-inch columns with cross arms. A universal column clamp is replacing the old-style cross arm. This clamp consists of three castings which serve to clamp a length of standard heavy 3-inch pipe at right angles to the drill column. The pipe can be slid back and forth through the clamp and may be of any desired length. This provides a more flexible drill set-up and permits drilling a wider face than was possible with the former type of cross arm.

From time to time drill instructors have been employed to teach the miners the best methods of drilling and breaking their rounds. As a result, although no standard round is insisted upon, most of the drift men use a round like that shown in Figure 11. This round is designed for 6 by 8 foot drift in hard ground.

Forty and sixty per cent strength gelatin dynamites are used in drifting, with No. 8 caps and fuse. Stemming is used. This is made by filling paper cartridges with screened table tailings from an old pond; the stemming is slightly dampened before being sent underground.

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Drift crews consist of a miner, usually working on the day shift, and two muckers working on the opposite shift. The usual practice is to drill and blast on one shift and muck out on the other. Timbering, when necessary, is done by the miner before setting up and drilling. Only rarely is the ground of such nature that overhead booms or spiling are required, as in some places in the Capote and Elisa mines. Frequently timbering is done on a separate contract after completion of the drift.

Shoveling sheets are laid before blasting. The broken rock is shoveled into 1-ton cars and trammed to the shaft. A mechanical shovel operated by compressed air was tried for drift work, but without success.

Raising. - Figure 10 shows a typical raise round. Hand-rotated stopers are used for this work, with 1-inch quarter-octagon hollow steel. Raise crews consist of a miner and helper on day shift and the same on night shift.

For long timbered raises an air hoist is set up at the bottom of the raise for hoisting timber and tools to the face. In one place on the 600 level a number of square-set raises were being driven at the same time. An air hoist was mounted on a truck and taken from raise to raise whenever timber was to be hoisted. In ordinary stulled raises, timber is hoisted by hand with a rope and tackle.

The raise men are usually required to tram their own rock to the shaft. Occasionally, if contract trammers are working in near-by stopes, they are given the raise tramming to do.

Supply System. - A crew of nippers deliveres sharp steel from the shop on the surface near the shaft to the steel racks on each level in the mine. The miners get sharp steel from the racks and return the dull pieces, which are then taken to the shop by the tool nippers. As almost all drilling is done on the day shift, the nippers work on night shift, so that each morning a supply of steel for the day's work is on hand.

Each level has a supply room where tools, drills, hose, and other supplies are kept. If a machine breaks down, the miner has only to take it to the supply room and exchange it for one of the spare machines. The tool nipper takes the broken machine to the surface and returns it when repaired. Hose is likewise repaired on the surface.

All timber is framed at the framing shed at Ronquillo and taken by the narrow-gage railroad to the mine timber yards. There it is loaded on timber trucks, hauled to the shaft, and lowered into the mine. On each level small amounts of timber are stored at points as close as possible to the working places so that contractors and miners will not waste time hunting for timber or hauling it long distances. Generally the timber for the stopes is lowered through raises from the level above. Wedges are not made into bundles but are shipped loose and stored in bins in the timber yards and underground.

The main powder magazine is at the upper end of the Capote basin. Powder is brought to the mines each day by railroad or truck. There it is loaded on the cages, distributed to the several levels, and stored in the underground

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magazines. Only one day's supply may be kept in the magazines. To be hauled into the mine, the boxes of powder are packed into strong, red-painted, locked wooden boxes, which are loaded on the regular timber trucks. Fuse from 3,000-foot reels is cut and capped at the surface at each mine. A day's supply for each level is packed into special containers and sent to the underground fuse magazines. The containers are carbide cans, lined with burlap and fitted with carrying handles. Miners get requisitions for their powder from the shift bosses. Powder and fuse are carried from magazine to working place in separate sacks made from discarded flotation-cell blankets.

Timber-Treating. - All shaft timber and all timber for permanet workings, such as main-haulage drifts and shaft stations, is treated with a preservative after framing and before being sent to the mines. The treatment is for the double purpose of increasing the life of the timber and making it resistant to fire.

The timber is chiefly Oregon pine from the Pacific coast. The preservative, a yellow powder, is a mixture of triolith (90 per cent sodium fluoride, 6 to 7 per cent potassium or sodium bichromate, and small amounts of phenols) and sea salt, bought in 675-pound barrels. The latter comes from natural deposits on an island in the Gulf of Lower California.

The solution was at one time mixed in a galvanized iron tank. After about two years of service the tank wore out because of the corrosive nature of the salt solution. It has been replaced by a redwood tank coated inside and out with a heavy asphalt-base paint. The tank is 4-1/2 feet square and 6 feet deep, having an effective capacity of about 850 gallons. The tank is filled half full of water, and the water is heated by turning in live steam. Four pails, or 112 pounds of triolith, is added and stirred and dissolves at once. Then 300 pounds of the sea salt is dumped in, the tank filled to the top with water, and the steam left on to heat the mixture and give some agitation. The salt dissolves in about two hours. The solution then has a specific gravity of about 10° Baumé.

There are two treatment tanks, sunk level with the ground near the framing shed. They are made of reinforced concrete 8 inches thick and have one side wall in common. Inside dimensions of both are the same; 6 feet wide, 24-1/2 feet long, and 6 feet deep. A 20-gallon-per-minute electric centrifugal pump is piped to transfer solution from one tank to the other. Steam lines of 2-inch pipe are supported on wooden blocks about 2 inches above the floor of the tanks, one tank having four and the other six lines lengthwise. Originally, small coils of 1-inch pipe with standard threaded fittings were used. These soon developed leaks due to corrosion, and were very difficult to repair. The present pipes are welded to avoid this trouble. Steam at about 40 pounds pressure is piped from the smelter power plant. Above the pipes, and likewise supported on wooden blocks, is a grating of old rail laid across the tank about 6 inches above the floor and spaced a foot apart.

Timber is loaded in and out of the tanks by hand. Plank and large pieces are laid evenly, with small strips of scrap lumber for vertical spacing, so that the solution can circulate freely around and through the pile. Blocks

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and wedges are dumped on a floor of boards and covered with boards on top. The wood is kept from floating by wooden bars wedged into slots in the concrete walls a few inches below the top of the tank.

The loaded tank is covered with a double layer of plank, and steam is turned into the pipes for about 12 hours, usually overnight. This dries and heats the wood, drives out some of the pitch, and makes it absorb the solution more rapidly. In the morning at 7 o'clock when the men go to work, the solution from the other tank, at a temperature of about 100°F., is pumped onto the new timber. After three to five hours it will have heated to 190 to 200°. The desired treating range is from 194 to 198°. Above this the loss of water is too rapid. When the solution is first applied, it is tested and brought to 5° Baumé, either by adding water or the strong fresh solution. The test is repeated after a few hours and enough liquid is added to keep the wood submerged. After eight hours, at 4 o'clock in the afternoon, the steam is turned off and the timber allowed to soak in the slowly-cooling bath until morning. The solution appears to penetrate the wood about one-fourth inch.

The capacity of each tank is approximately 4,500 board feet of ordinary mine timber. As much as 107,000 board feet has been treated in a month. During the first half of 1929 about 380,000 board feet of timber, or one-tenth of the total mine consumption, was treated; 3,950 pounds of triolith and 11,200 pounds of salt were consumed.

Stoping Methods

At one time or another Cananea has offered examples of almost every known mining method.[5]

In 1910 eight or more mines were in operation, producing ore by a half-dozen distinct methods. At Puerticitos a low-grade ore in garnetized limestone was being mined by surface benching. Primary breaking was by means of 22 to 24 foot hand-drilled holes, blasted with black powder. A large proportion of waste was sorted out to produce a 4 per cent ore, and 75 to 80 per cent of the material broken was discarded. The mining efficiency was 4-1/2 tons of ore and waste per man-shift. Square-setting was in use, but chiefly as an auxiliary to other methods, accounting for not over 5 per cent of the total production. Its cost was relatively high, varying from $1.20 to $1.40 per ton of ore in the chutes for mining and timbering only. Top slicing held first place as a producer. This differed little from the method as used to-day. It gave a low stoping cost of $0.60 to $0.70 per ton of ore in the chutes. A combination shrinkage and caving system was used under certain conditions, which consisted of shrinkage stopes and the caving of pillars. The stopes were carried up to capping or stoped ground above, after which the pillars crushed or were blasted out. No timber was needed, and a cost of $0.40 to $0.50 per ton was attained. A cut-and-fill method was in use in the hard ores of the Elisa mine, where the stopes were sometimes as large as 75 by 100 feet. The method differed from the modern cut-and-fill method in that no floor was used and in that sorting was necessary, as about 50 per cent of the rock broken

5 - Elsing, M. J., Mining Methods Employed at Cananea, Mexico. Eng. and Min. Jour., vol. 90, Nov. 5, 1910, p. 914; vol. 90, Nov. 12, 1910, p. 963.

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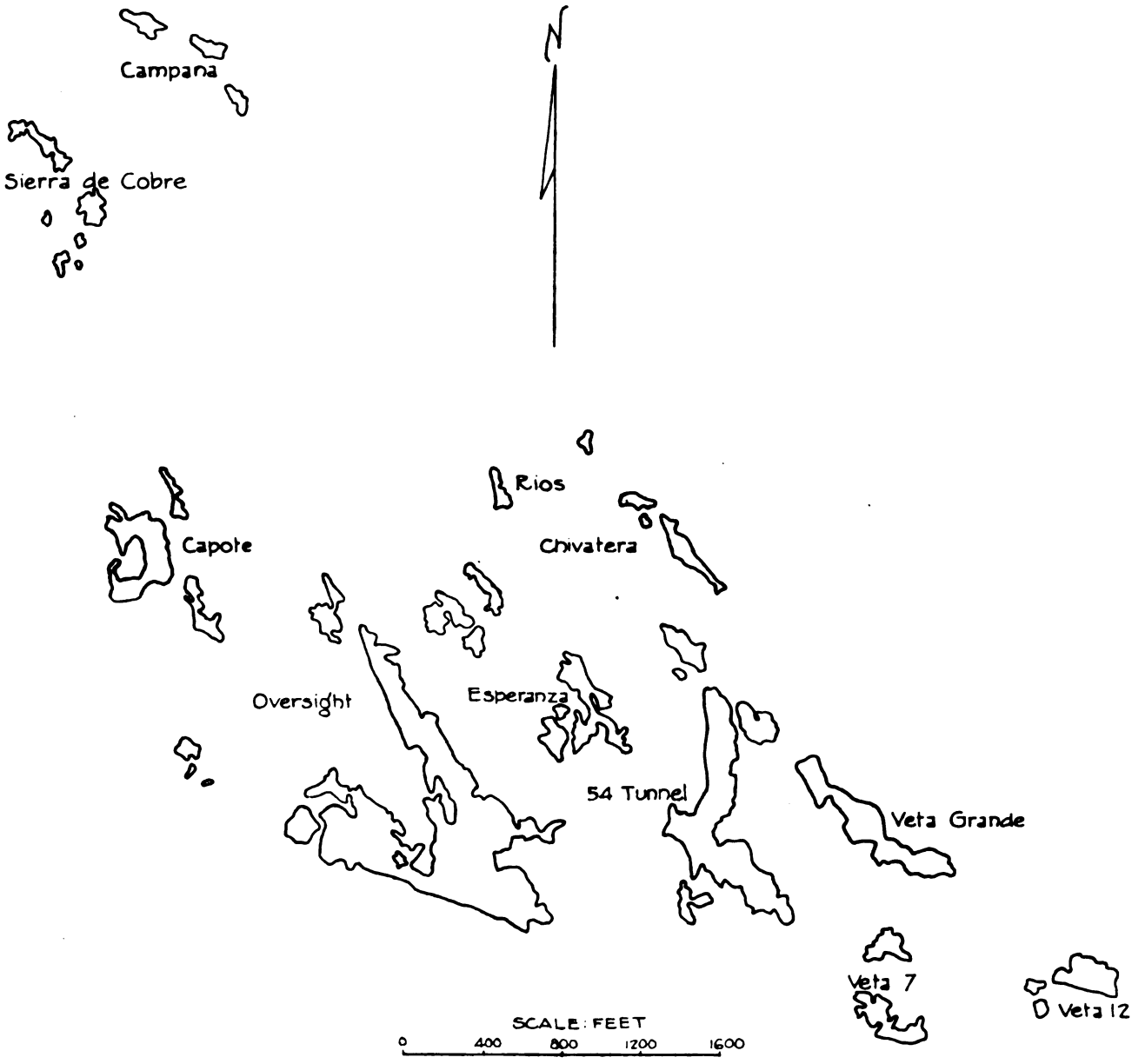

FIGURE 13.- HORIZONTAL PROJECTION OF STOPES IN CAPOTE BASIN

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was waste. To prevent the loss of fines the ground was broken as coarsely as possible. Finally, what was known as pyramid stoping was carried on in the Veta Grande. This was a combination of square-setting and shrinkage stoping. Blocks 40 by 50 feet were laid out by square-set drifts on the sill floor. From the drifts a double row of square sets was carried up all around the block. The 30 by 40 foot solid core in the center was mined out by shrinkage stoping, the excess ore being drawn out through the square-set chutes. Waste was necessarily mined and trammed away. When all the blocks in a given section had been mined, the broken ore remaining in them was drawn out. Pyramid-shaped piles of ore would still be left in the middle of each stope, and these gave the system its name. They were removed by running drifts through the centers of the blocks, with one or more chutes to tap the broken ore above. The cost of stoping by this method was 80 to 90 cents per ton.

At present the Capote, Veta Grande, and Colorada are using shrinkage, cut-and-fill (both horizontal and inclined), square-setting, top-slicing, and undercut-caving methods. This diversity of methods is chiefly due to the great natural variation in ground conditions and ore occurrence. Occasionally previous development or mining, plans for future operations, or the security of shafts or surface plant are the deciding factors in choosing methods.

Figure 13 shows that the ore bodies worked by the Capote and Veta Grande are very irregular in size, shape, and distribution. In this area, moreover, the wall rock is generally weak. Square-setting and top-slicing, consequently, have accounted for most of the tonnage from these mines. These methods, however, are better described in connection with the Colorada. The Capote is using, in one section, an undercut caving method, which will be described.

The ore and walls in the Colorada are of such nature that little or no support is necessary when mining. On the 600 and 700 levels, where the ore shoot is in effect a vein (fig. 4), long filled rill stopes were laid out as offering the cheapest method consistent with safe working conditions and complete extraction. Some of these are being converted to horizontal cut-and-fill. Below the 700 level the ore ring becomes much thicker, and just below the 900 the waste core disappears completely. It was evident that if the cut-and-fill method were to be used, pillars would have to be left to support the walls and then removed by some other method, either by top-slicing, which might allow a general subsidence of ground above, or by the Mitchell slicing method, attempting to fill so as to prevent any general caving. The former course promised more certain recovery of all the ore. Therefore, it was decided to use top-slicing for removing pillars from the 800 to the 1,000 level. Below the 1,000 it is planned to top-slice the entire ore body. However, if production requires the opening of stopes on these lower levels before the top-slicing of pillars above is finished, cut-and-fill stopes will be laid out as described with pillars between to be mined by top-slicing.

Near the shaft and between the 500 and 600 levels, although the walls are solid, a part of the ore is so shattered and blocky that square-setting, with small sections and close filling, was the only possible method for use. This area was started as a square-set stope. A small section adjacent to it was started as a rill cut-and-fill, but was likewise found unsuitable for this

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method, which was changed to the square-set.

Above the 500 the ore was of relatively low grade and the vein narrow. Some of the first production from the Colorada came from the shrinkage stopes. A disadvantage of shrinkage stoping in this case is that the ore after remaining in the stope for a short time oxidized so as to interfere seriously with flotation. This is generally true here where the ore occurs in diorite porphyry. At present, the material being drawn from this stope is of very low grade, and a large part of it is being used for waste fill in the stopes below.

Filling is an important phase of both square-setting and cut-and-fill stoping. As much as 5,000 tons of waste is sometimes required for filling one floor of a cut-and-fill stope. Most of this waste at present comes from two surface glory holes, but a small amount is from development work. One glory hole is over a 500 level tunnel which extends through a small ridge between the Colorada ore bins and the Kirk shaft. The other is above the 500-level ventilation adit.

Table 2 shows some comparative stoping costs for Colorada stoping methods.

Table 2. - Partial stoping costs, Colorada Mine, August and September, 1929

	Square-set	Horizontal cut-and-fill	Rill cut-and-fill
August, 1929:			
Tonnage	9,353	15,577	8,539
Labor	$0.6101	$0.4829	$0.5421
Explosives	.0787	.1054	.1689
Timber	.7156	.2252	.2142
Partial totals	1.4044	0.8135	0.9252
September, 1929:			
Tonnage	8,980	18,483	8,775
Labor	$0.5332	$0.5146	$0.4482
Explosives	.0691	.1562	.1110
Timber	.5436	.2789	.3509
Partial totals	1.1459	0.9497	0.9109

These figures are for ore delivered to chutes on haulage levels, and include breaking, timbering, and mucking. Stope bosses are included in "labor." Supplies, drills, and air are not included, as these are distributed evenly to all ore, amounting to a total of 17 cents per ton in August and 20 cents in September. Filling is charged similarly and amounted to 17 cents per ton in both August and September.

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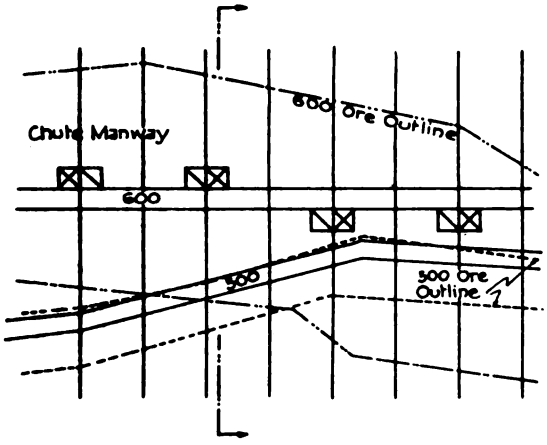

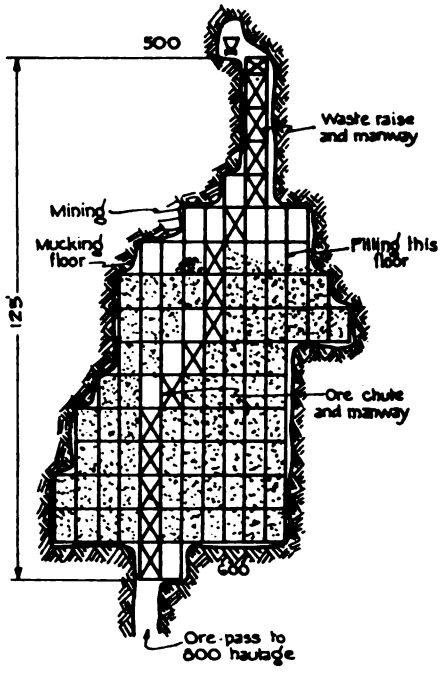

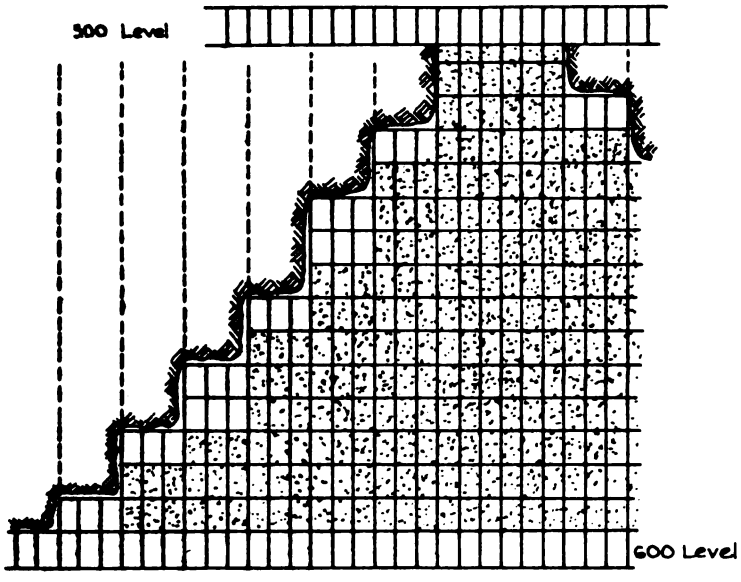

FIGURE 14.- SQUARE SET STOPING

SCALE: FEET

0 10 20 30 40 50 60 70

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Square-setting. - The square-set stopes lie between the 500 and 600 levels, extending over a length of about 200 feet. The vein averages 60 feet wide on the 600 level and 20 feet on the 500 level (fig. 14). A drift was run in the center of the vein on the 600 level and timbered with sill floor square-sets. From it two-compartment six-post raises were driven to the 500 level at intervals of 30 feet along the vein. These raises are on the dividing line between the 15-foot stope sections and are offset as they go up to keep them as nearly as possible in the center of the ore. One compartment is a manway and the other a chute. The raise serves for entrance for men, lowering timber and tools into the stopes, dropping waste fill, and extracting the ore. Each raise serves two sections. Eleven feet above the floor of the 600 level, a 15-foot section is mined across the ore body, in both directions from the raise, and is timbered with standard 10 by 10 inch square-sets. Posts are stood on the solid and the floor is fitted around them. The floor consists of a single layer of 2 by 10 or 2 by 12 inch plank 10 feet long, laid on sills of doubled 2 by 10 inch plank. The sill is not taken out because to do so would make the maintaining of the drift difficult. Eleven feet, the usual height of a top-slice floor, is left because top-slicing is to be used to remove the sill after square-setting is finished. The ground over the drift but below the stope floor is taken out and a bridge cap put in (fig. 12).

Another floor is mined next by starting at the raise and blasting the ore down on the first floor where it is shoveled into the chute. The sides of the stope are next lagged inside the posts with 2 by 10 inch plank, and the posts are laced top and bottom from one side of the stope to the other with wire rope. This rope is obtained by unstranding discarded hoist cable and is made up on the surface into 40-foot lengths and coiled for convenient handling. This lacing is necessary to prevent the weight of the fill from breaking out the gob fence when the adjacent section is brought up. Fill is now run in from the level above and spread by hand or occasionally by single drum scrapers or slushers. A temporary floor is then laid over the fill. Mining and filling are now carried on together, mining on one side of the raise and filling on the other, thus speeding the work and leaving as little ground open as possible --never more than two floors. Where the vein is wide a second extraction chute may be made by lagging-off sets before filling. Adjacent sections are started and kept within two or three floors of the preceding one, as shown in Figure 14. This order is maintained strictly, to prevent the formation of high vertical brows. For the same reason lead sets are always taken on the side next the gob; often three or four sets are carried in advance of the stope to break the corner of the brow before it falls of its own weight and crushes the floor below. Very careful blocking is necessary. Wheelbarrows are generally used for spreading the fill and moving the ore to the chutes, although slushers are very satisfactory and are being used whenever available.

No tramming is done on the 600 level. When the stope raises were being driven to the 500 level, temporary chutes were built in the drift sets, and the ore from the raises was trammed to the shaft. Before stoping began, ore passes had been brought up from the 800 level, with fingers to each of the square-set stope raises, so that all the ore from these stopes is dropped to the 800 haulage level.

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The square-set stopes have produced a small amount of first-class or smelting ore. No special provision is made for handling two classes of ore, however, and no sorting is done in the stopes, either for waste or for high grade ore. If the ore drawn from the 300 level happened to reach the required grade, it was taken for first class. Experience enables the bosses to estimate grades closely enough to separate first-class ore by inspection.

Square-set stope crews consist usually of a miner, a helper, and two muckers (same on both shifts). Drilling is done with jackhammers and 1-inch hollow-round steel, and four or five flat 5-foot holes are drilled to a set. Only 40 per cent gelatin powder is used. A square-set averages 200 cubic feet.

Shrinkage Stoping. - In the Colorada mine some shrinkage stoping is being done above the 500 level in a relatively low-grade ore shoot which varies in width from 10 to 20 feet (fig. 15). A drift was driven in the ore on the 500 level along the hanging-wall side of the vein. From this drift, at about 30-foot intervals, raises were driven in the ore to 40 feet above the level. At that elevation a connecting drift was run from raise to raise and silled out to the full width of the ore to form the base of the stope. Three of the raises, as shown, were driven as two-compartment stulled raises. The one in the center of the stope was pushed up as quickly as possible to the 200 level, for ventilation. Later on it also served for a time to lower supplies into the stope. No attempt was made to maintain it through the broken ore in the stope. In the raises at either end of the stope the divider stulls were hitched from wall to wall of the stope, and the manway was kept open permanently. As the stope went higher the ore diverged more and more from the vertical ventilation raise. For a time an entrance was kept from it to the stope, forming a narrow vertical slot in the hanging wall. Finally, however, the two end raises, which were carried considerably in advance of the stope, were connected to the 200 level and the center raise was abandoned.

To preserve the 200-level drifts, which now gave access to the stope, and in which a series of grizzlies was to be installed, a 35-foot pillar was left below the level and the stope started anew above it as was done on the 500 level. The upper and lower parts of the stope were connected by raises through the level pillar, and 10-inch steel rail grizzlies were built over each raise on the 200 level. This was done to eliminate the blasting of bowlders in the 500-level chutes. A large part of the production of this stope is now being used for waste fill in stopes below, and it is desirable to be able to load the trains rapidly with waste for plugging bowlders in the chutes.

Above the 200 level the stope is being carried up as before. Connection has been made to the 100 level for ventilation, and the two end raises are being driven to the surface. A large pillar will be left to protect the main 100-level drift as long as needed, and the stope will be carried through to the surface.

Drilling is done with stoper machines, the drillers standing on the broken ore in the stope. Vertical holes 8 feet deep, three or four to a row across the stope and spaced 4 feet apart, are each blasted with four to six sticks of 40 per cent gelatin dynamite.

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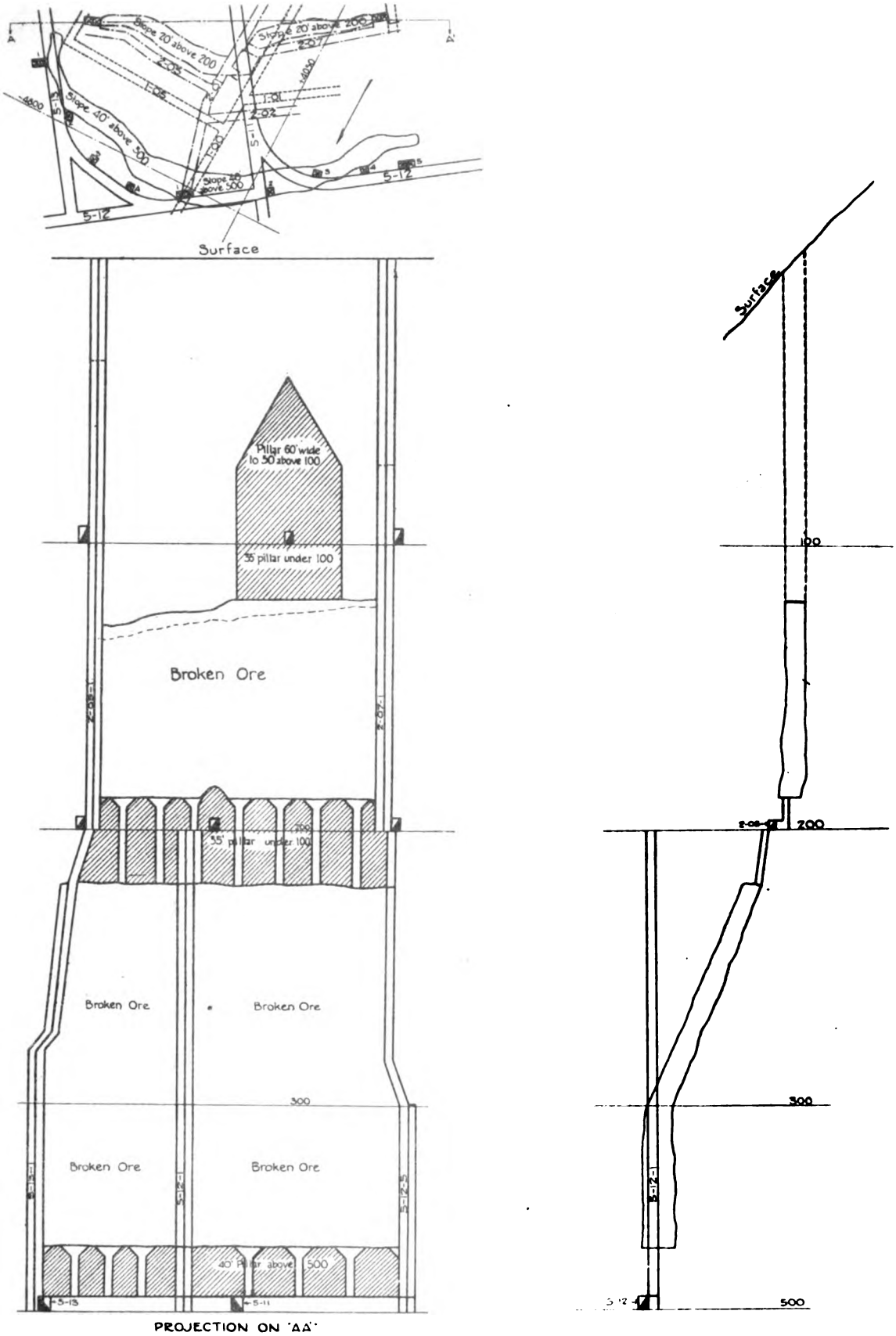

PROJECTION ON 'AA'

FIGURE 15.- SHRINKAGE STOPE. "LA COLORADA" MINE

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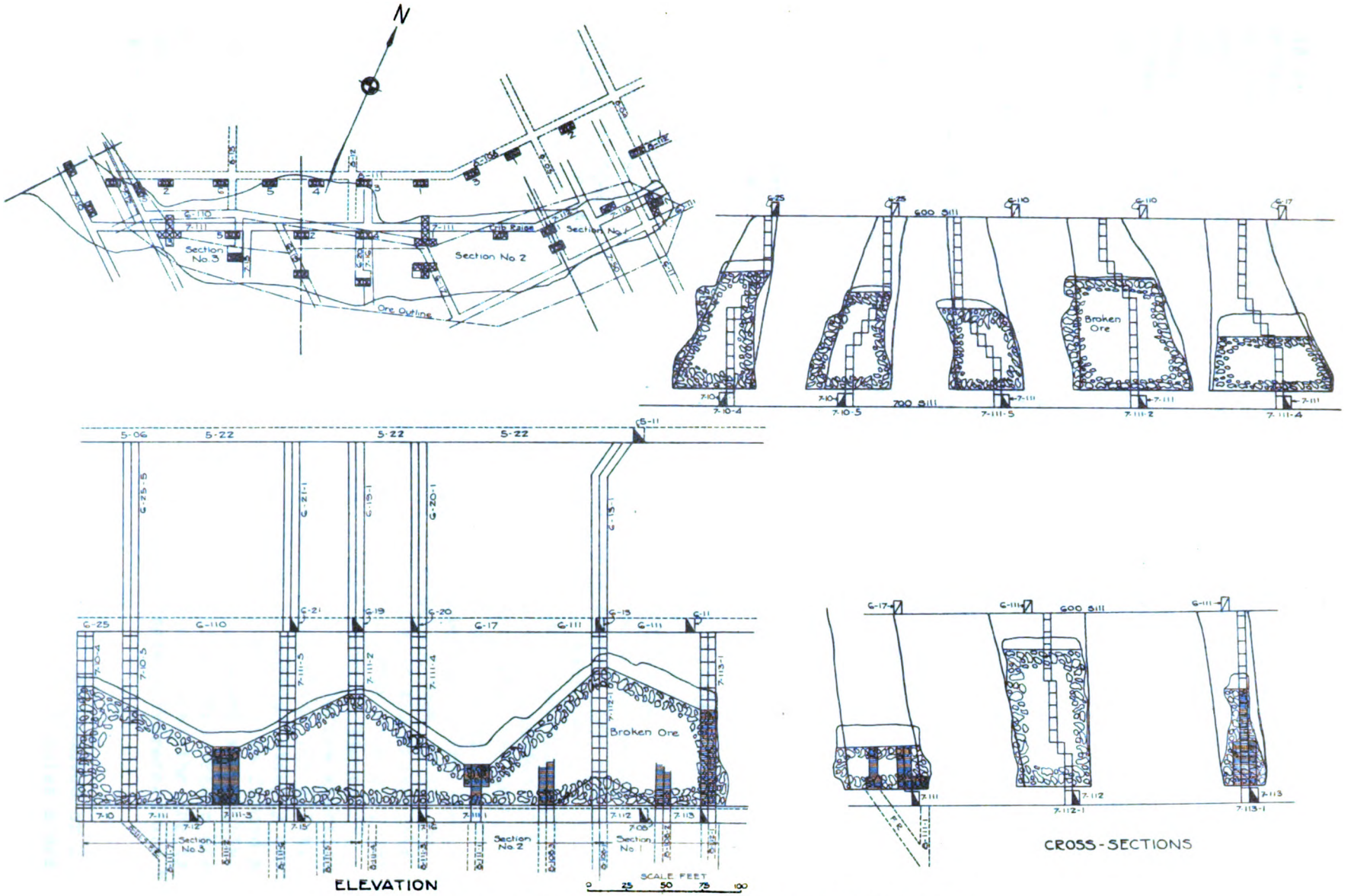

FIGURE 16. - FILLED RIII STOPE IN "LA COLORADA" MINE

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The Colorada shaft is about 300 feet north of this stope. The 100 level is an adit level on the same elevation as the shaft collar. The stope has two purposes besides that of producing ore; the more important is to establish a break line on the side of the ore body next to the shaft, that will prevent the expected subsidence from extending to the shaft; the other is to provide a means of filling above the top-slice stopes to be worked from the 600 to the 900 level. The broken material in the shrinkage stope will settle down over the top slices, where otherwise dangerously large openings might form. Additional waste to keep the cut full will be obtained by glory-holing on the surface on the up-hill side of the stope.

To make a clean break line, the pillars on the 100, 200, and 500 levels will be removed when the stope is finished. The one above the 500 may be stoped for ore by cut-and-fill mining, or, like those above, may be allowed to go for waste. They will be partly or completely removed by cutting the block with drifts and raises and blasting out the remaining small pillars.

Rill Cut-and-Fill. - The rill cut-and-fill or filled rill stoping method is now accounting for 25 to 30 per cent of the Colorada production. Figure 16 shows plan and sections of one such stope on the 700 level.

Here the ore averages about 60 feet thick on the 700 level and 40 feet on the 600 level. It is hard and compact, though blocky, and stands well over the required widths.

A drift was driven about in the center of the vein and timbered with regular square-set timber. From it stulled raises were driven to the 600 level for waste-fill raises. They were continued from the 600 to the 500 level, where the waste is brought in. Meanwhile, ore passes were raised from the 800 to the 700 level at points halfway between the waste raises. The stope was next silled out for its entire length at a height of 11 feet (one top-slice floor) above the 700 rail. The ground was broken by breast stoping, carrying a face the width of the ore and pulling the broken ore to the chutes with scrapers. At this time the 2 or 3 feet of ore above the drift timbering was also taken out and a bridge cap placed over each set. A floor of 2-inch plank was laid in the stope, the extraction chutes were cribbed up to the back, and waste was run in from the 500 level and spread to within 3 feet of the back. Mining was then begun by taking out ground on both sides of the waste raises in inclined slices 11 feet thick and filling with waste after each cut, until the back of the stope was given the saw-tooth profile shown in Figure 19. Floor is laid on the slope each time after filling with waste and before starting to mine. The floor consists of 3-inch plank nailed to other plank for sills. With so wide a back the slope of the rills could not be carried steeply enough to run the ore into the chutes by gravity, because this would have formed a dangerous "belly" directly above the chute. Therefore scrapers and double-drum air hoists are used to move the ore and to spread the fill. The broken ore drops to the motor chutes on the 800 level. Above the 600 level the ore is not so wide, and it is expected that the slope can be safely increased and the use of scrapers abandoned.

Drilling is done with Leyner-type drifter machines, mounted on 3 or 4 inch columns. In advancing up the slope of the rill, 10-foot holes spaced

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about 5 feet apart both ways and given the same pitch as the back of the stope break a 10-foot round across the width of the stope. Four to six sticks per hole of 40 per cent gelatin dynamite with No. 8 caps and fuse are used. Considerable trouble is experienced with the ground's breaking in huge bowlders. Blasting with 60 per cent dynamite corrects this to some extent. "Space blasting" with 60 per cent dynamite which has given good results elsewhere is being tried as another means of breaking the rock more completely. The chief fault of the present method is that the explosive is concentrated in the bottom of a long hole. In space blasting, three sticks of powder, including the primer, are tamped in the bottom of the hole. A 1-inch round stick of wood 10 inches long is inserted, the next stick of powder is tamped on top of it, and so on until enough powder has been used. The hole is then sealed with two or three sticks of stemming. As the holes are 1-5/8 to 2 inches in diameter and the spacers are only 1 inch, detonation is complete, yet the force of the explosion is better distributed and fewer larger bowlders result.

The extraction chutes are generally carried three compartments wide, and the scraper hoist is set up directly over the center compartment. Thus, the hoist can serve both slopes from the same set-up merely by swinging around on its column. At the point where the outside compartments join the center one, the heavy ore has a tendency to cut away the cribbing. To avoid this, swinging curtains made of old rail are placed over the tops of the chutes. The ore as blasted down is very coarse, so that only about two-thirds of it will go through the grizzlies without secondary breaking. Small bowlders are broken with hammers and larger ones with compressed-air concrete breakers. These machines use moils made of special alloy steel, with collars shrunk on instead of forged. The moils do not break, in spite of the severe usage. The machine weighs 79 pounds, which makes it difficult to handle under the conditions. However, it is so effective that it is considered almost essential, especially by the contractors. In addition to this work on the grizzlies, some plugging is necessary on the slope of the rill to break the largest slabs before attempting to move them with the scraper.

Stope crews consist of two muckers and two miners on both shifts. One stope boss directs the work of three or four stopes. The same crews are given contracts both for mining and filling.

Horizontal Cut-and-Fill. - The application of the horizontal cut-and-fill method is well illustrated in the stopes between the 800 and 1,000 levels. Figure 17 shows the stope layout and haulage drifts for part of the 1,000 levels. Stopes and pillars from the 900 to the 800 level are laid out exactly over those on the 1,000 level. The typical stope is 30 feet wide, from 50 to 160 feet long, and has a row of raises along the center line at 40-foot intervals. These raises, as well as the corresponding raises in the center of the pillars, are driven from the 1,000 to the 800 level as stulled raises, except that they are cribbed for about 20 feet above the rail. As the 900-level stopes are to be worked at the same time as those on the 1,000 level and as there is to be no ore haulage on the 900 level, the pillar raises are branched to tap the stope raises at the 900 level and will handle the ore from those stopes.

On the 900 level the stopes were silled 11 feet above the rail. On the 1,000 level, to protect the haulage drifts, the stopes were silled 22 feet

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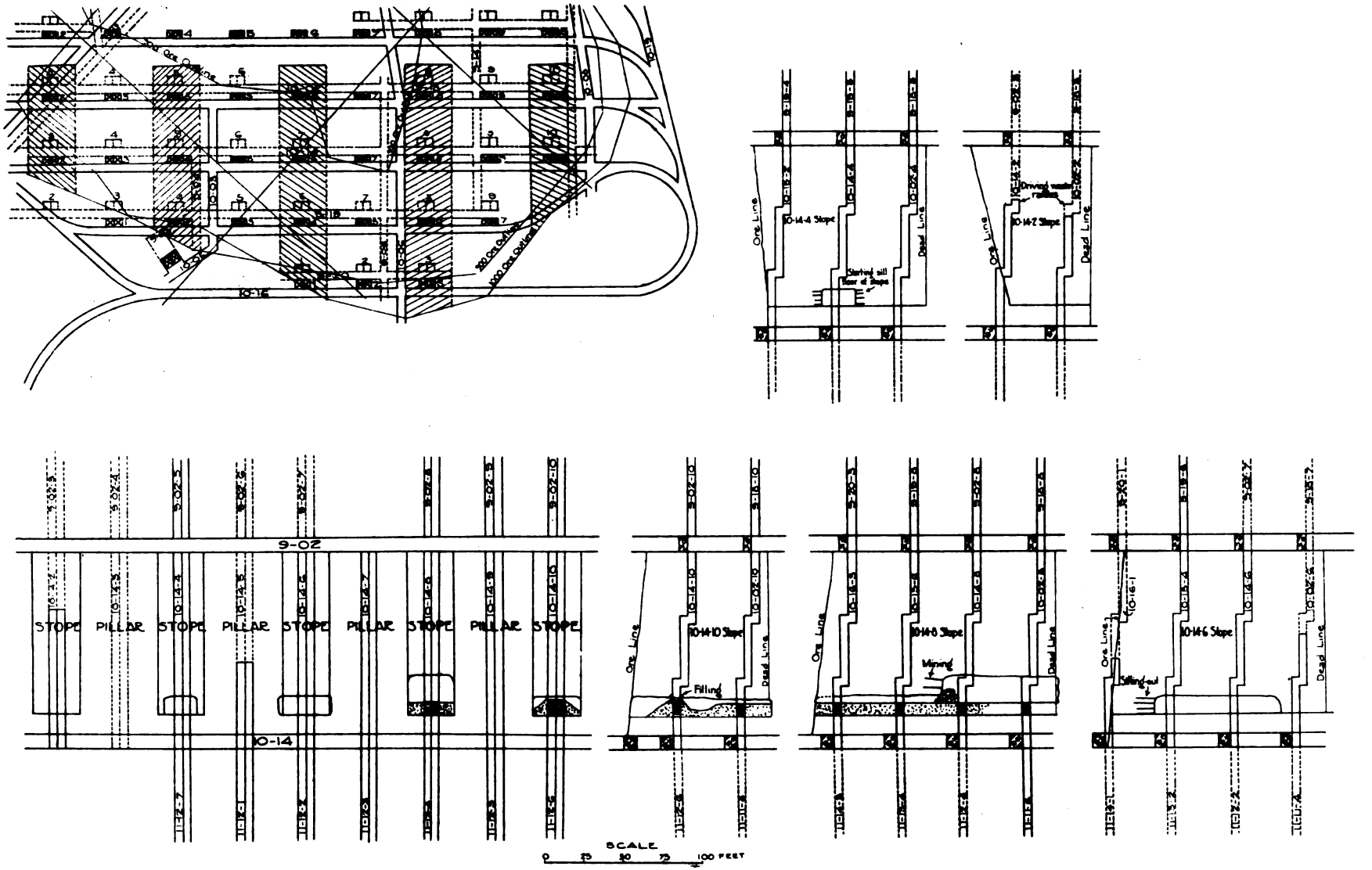

FIGURE 17. - HORIZONTAL CUT AND FILL STOPES IN LA COLORADA MINE

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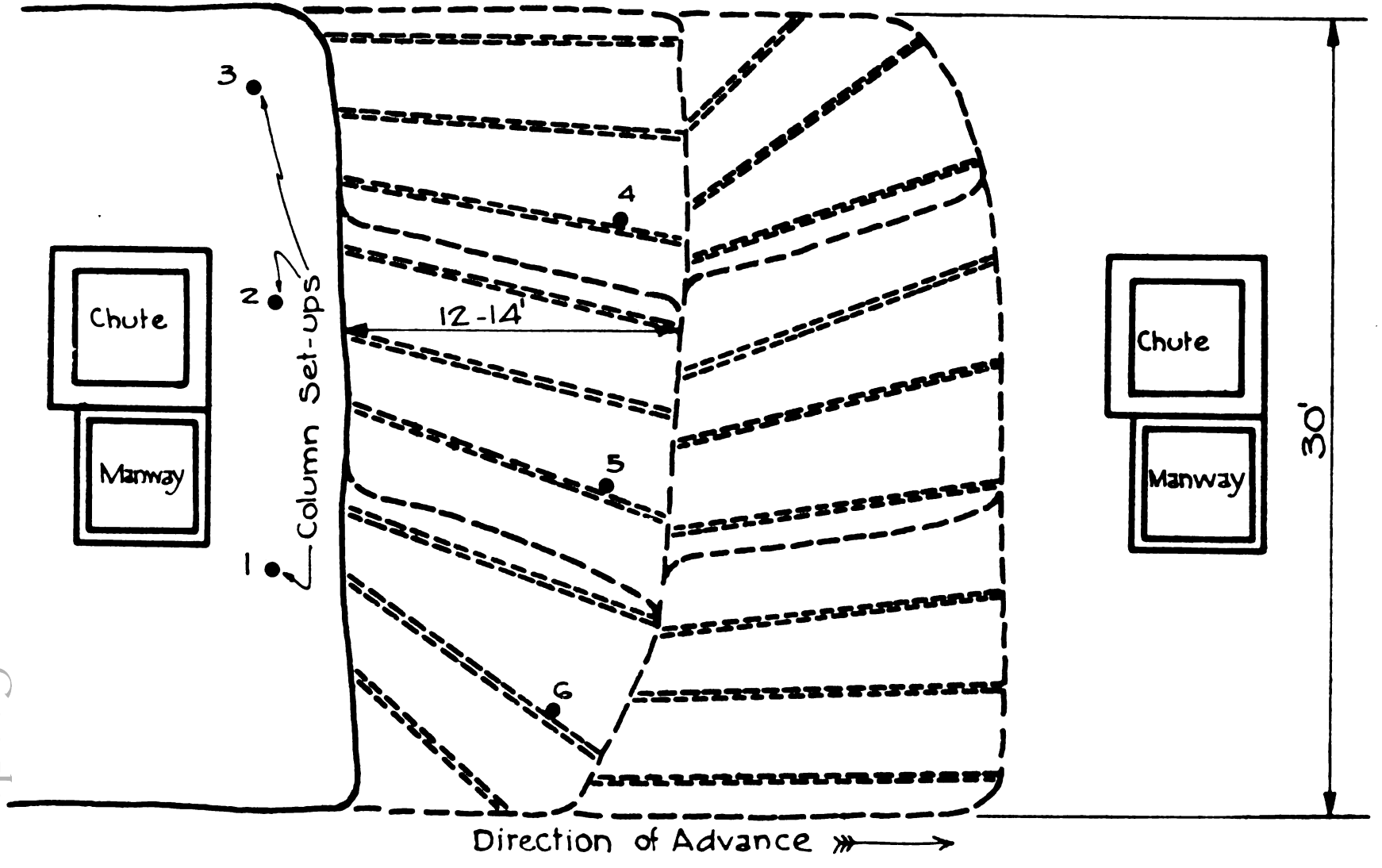

FIGURE 18.- DRILL ROUNDS FOR SILLING OUT CUT AND FILL STOPES

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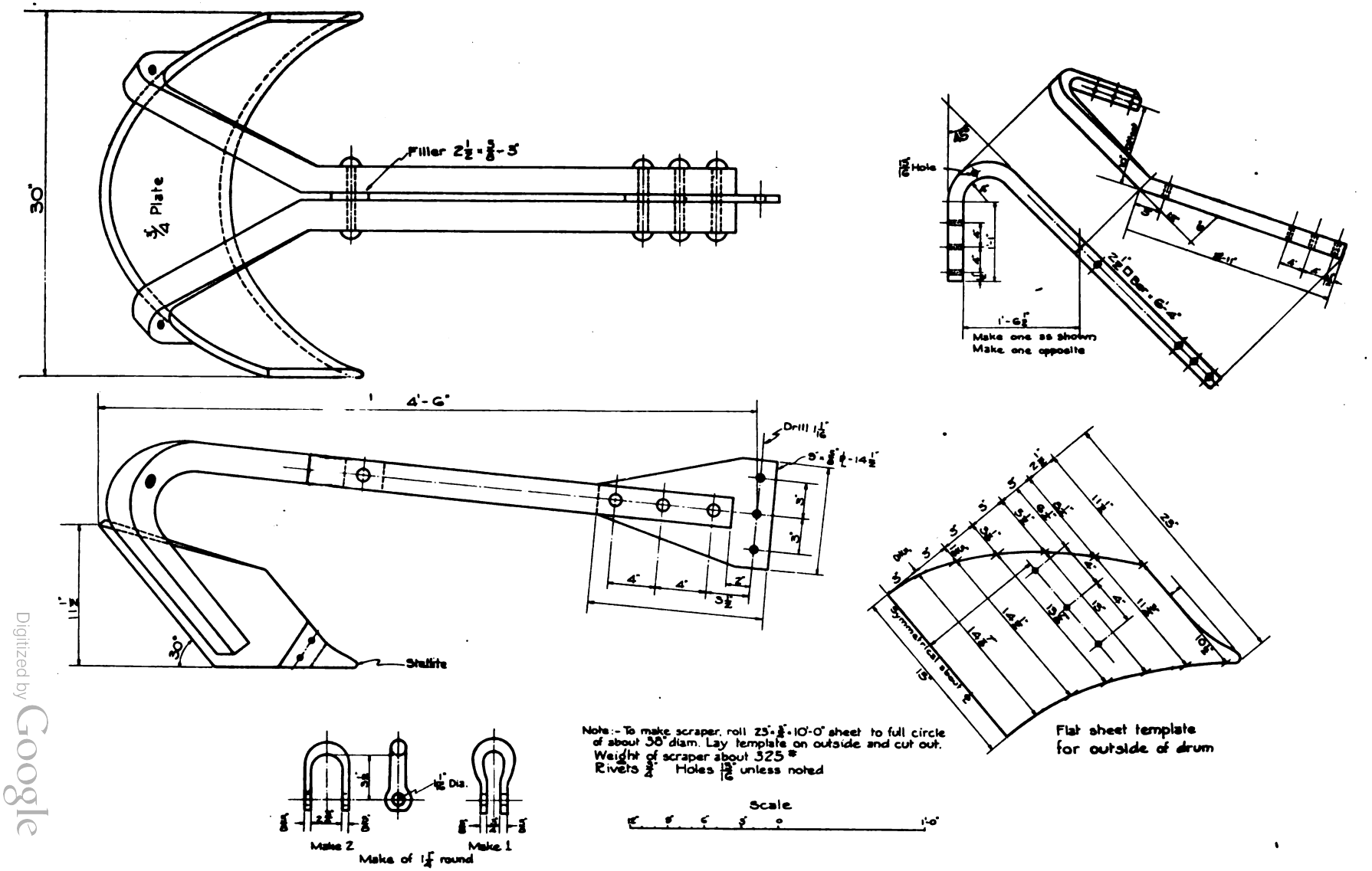

Note:- To make scraper, roll 25"-⅜"-10'-0" sheet to full circle of about 30" diam. Lay template on outside and cut out.
Weight of scraper about 325 lb
Rivets ¾" Holes 13/16" unless noted

Flat sheet template for outside of drum

FIGURE 19. - CRESCENT SCRAPER

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above the floor of the drifts (two top-slice floors). From the stope raises the ground is taken out to the side line on either side of the stope, giving a face 30 feet wide and 11 feet high. This face is now advanced by breast stoping. Figure 18 shows the method of drilling. Each row of holes consists of four or five flat holes spaced 3-1/2 to 4 feet apart vertically. Some plugging and secondary blasting is done, but most of the bowlders can be broken by hand. Pavement breakers are used in these stopes for breaking large bowlders. Drilling is done with heavy drifter-type machines mounted on 4-1/2-inch columns. As in drifting, a universal clamp with heavy 4-inch pipe for a cross arm is found more satisfactory than the rigid arm formerly used. With cross arms up to 4-1/2 feet long three or four rows of holes can be drilled from one set-up.

As soon as a stope is large enough a scraper is installed to move the ore to the chutes (fig. 19). Single-line slushers have been used, but the ore breaks too coarse to be moved by a light, hand-held scraper.

The extraction raises are built up directly under the stulled raises. The manway side of the raise is cribbed throughout with 4 by 10 inch timber. The chute side is timbered with 10 by 10 inch cribbing for the first 50 feet and above that with 4 by 10 inch cribbing. Chute lining is unnecessary with the large size of cribbing, whereas when the lighter timber was used the chute not only had to be lined but the lining had to be replaced once or twice during the life of the stope; this caused delays and used almost as much timber as is used under the present plan. The chute compartment is covered with a grizzly of 30-pound rails, and the ball and rib are cut off at the ends and the base bent down to fit over the outside of the cribbing. Grizzly openings are 10 inches. The manway is kept covered with timber, leaving just enough room for a man to get through.

When the breast has advanced past a second raise, the first part of the stope is cleaned out and a floor of 2 by 10 inch plank 10 feet long, nailed to 4 by 10 sills is laid. The sills are placed parallel to the direction in which top-slicing will advance underneath. Gob fences are built around the stope, except on the waste sides. These are made of 2 by 10 inch plank, nailed to other plank in place of posts. The space between the fence and the wall is filled with ore. The grizzly rails are now removed from the chute, the extraction raise is cribbed up to within 3 or 4 feet of the back, and both compartments are tightly covered with heavy timber. Generally the outside of the raise is covered with light scrap timber to keep waste out and to give additional rigidity so that the falling waste will not shift the raise out of position.

Fill is run in through the waste raises and spread by scraper and wheelbarrow to within about 3 feet of the back. The waste from the Colorada glory hole is hard and coarse, but the smaller amount produced by the Kirk glory hole is fine and when available is used for the top foot or two of fill for convenience in leveling and laying floor.

After filling, a temporary flooring of 3 by 10 or 3 by 12 inch plank is laid on the waste and the second cut started. The method of drilling and blasting is different now from that described, as the ore has a free face underneath. Flat holes 5 feet apart horizontally and vertically, 12 feet long, and

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drilled straight into the face break the ore readily; four to eight sticks of 40 per cent powder are used per hole. The only difficulty is to break the ore fine enough to handle. Where it has a tendency to come down in large slabs and blocks, small timber cribs are built up from floor to back and the ore is blasted down against their support. This tends to eliminate the hugh bowlders. In the future, space blasting will be used in these stopes, as well as in the rill stopes. Occasionally cribbing is needed behind the face to support the back. Carrying the back 2 or 3 feet higher in the center than at the sides gives an arch that reduces the trouble from loose back.

Top-Slicing. - In the Colorada mine, top-slicing will be applied to mining pillars between finished cut-and-fill stopes. These pillars will be 40 or 50 feet wide and 60 to 100 feet or more long. They will be already partly developed by drifts along their center lines and by raises from these drifts, generally at 40-foot intervals. In addition, some of these raises will have inclined branches or fingers extending toward the edges of the pillars which have been used for drawing ore from the cut-and-fill stopes on the level above. Above the 900 level the pillars will be only 40 feet wide and disconnected. Above the 1,000 level, as shown in Figure 6, they will be 50 feet wide and spaced 30 feet apart along a central 40-foot pillar which runs through the long dimension of the ore body.

These blocks will be mined in one or two sections, depending upon the number of working places desired. One or two headings, therefore, will be driven lengthwise through the pillar on the top floor, intersecting the raises or the fingers, and past the end of the block into country rock where they will connect with a permanent manway raise. They will be driven as small as possible, about 3 or 4 by 6 feet, leaving 5 feet of solid between them and the filled or caved stope above. Mining will be started at the end of the heading away from the manway. A 5-foot cut, 11 feet high (the standard height of top-slice floors), will be carried from the heading to the old fill or the dead line on either side. The sills of the old floor will be caught up by 8-inch round posts and head blocks. Long head blocks are used to spread the weight. Posts are stood on the ground without foot blocks. Another 5-foot cut will now be drilled and blasted. Slushers will be used to move the ore into the chutes. After each cut, or as often as an area at least 10 by 10 feet is available, floor will be laid consisting of 2-inch plank 10 feet long nailed to doubled sills of the same material. The sills are laid parallel to the direction of advance of the stope for convenience in picking them up when taking out the next floor. Two to four cuts (10 to 20 feet) will be taken out before shooting down, depending upon the weight that develops. In preparation for this, a light gob fence is built consisting of 2-inch plank nailed to the row of posts nearest the face. If the stope is being worked in two sections, it will be necessary to carry one section 30 to 40 feet ahead of the other and put up a similar fence along the dead line before shooting down the advance section. All posts except those in the gob fences will be drilled with air augers and blasted with a stick of powder each. These shots are timed so as to bring the floor down as smoothly as possible and more or less intact.

Headings are started on the floor below as soon as possible, so that when the first floor is finished mining can be started at once on the

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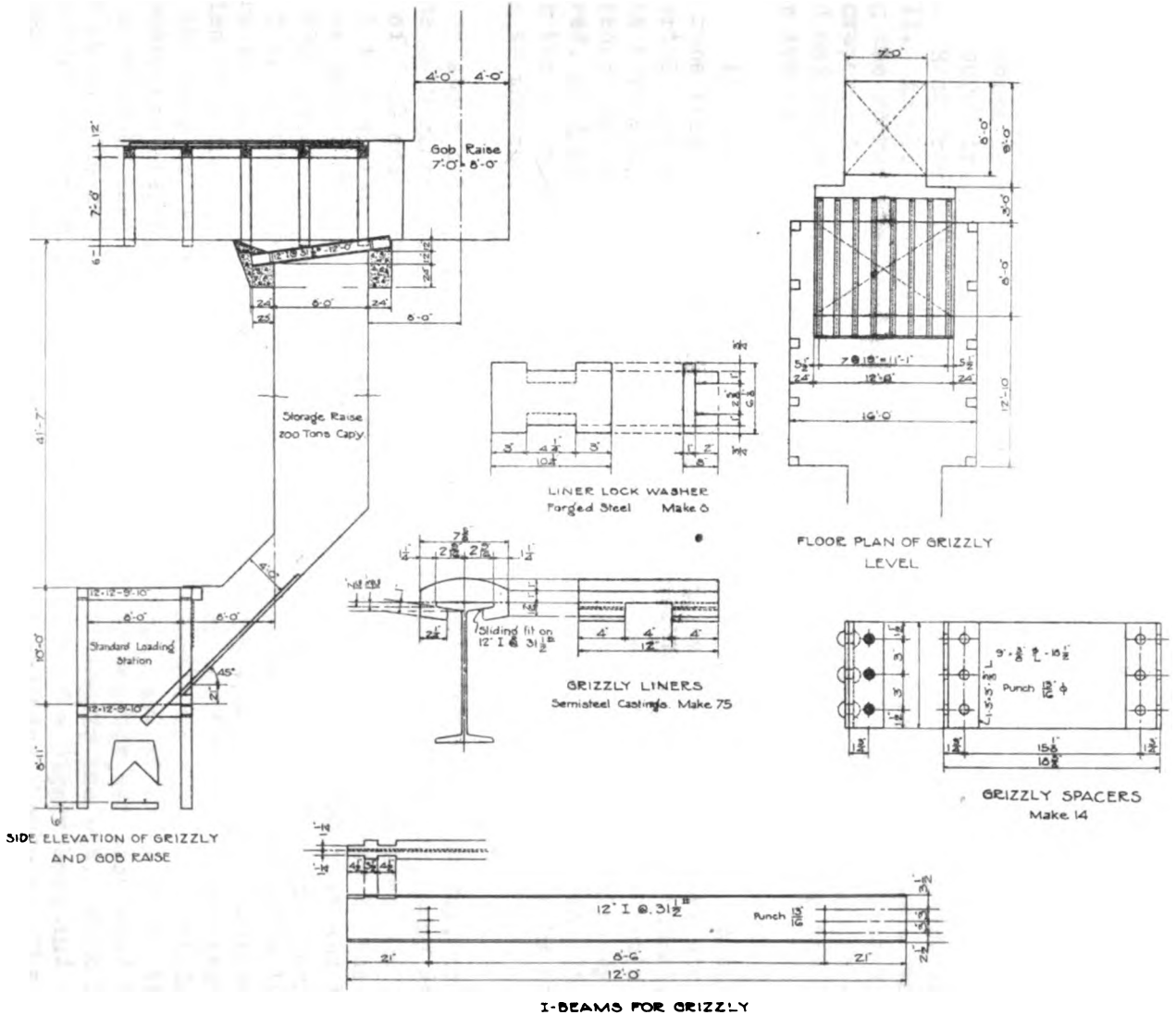

FIGURE 20.- GRIZZLY AND STORAGE RAISE

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floor below. Possibly two or more floors may be worked at one time. In that case, it would be necessary to keep the lower floor at least 40 to 50 feet behind the upper to avoid interference. When two sections or two floors are being mined close to each other, it is desirable to arrange the work so that they can be shot down at the same time. Otherwise the jar and pressure adjustments caused by one coming down may cause the other to drop before it is intended. Manways in the raises will be maintained for bringing in timber and for entrance to the stope, thus giving at least two exits from each working place and aiding ventilation as well. It is believed that in these stopes both shifts can drill, blast, muck out, and timber a 5-foot cut across the stope.

Waste Glory Holes. - Waste for filling the square-set cut-and-fill stopes comes from several sources. A small amount, averaging about 200 tons per day, comes from development work. This is hoisted on the cages to the 450 level, dropped in a pocket there, and hauled by one of the waste transfer raises. Rock from any incidental surface excavation in the mine yards is used for fill. An old dump near the Kirk shaft is being used for the same purpose, loading the rocker dump waste cars with an air-operated shovel or with a dragline scraper. All these are sources of finely-broken material which is easily handled and spread, and which, therefore, when possible is used for the last foot or two of fill in a stope.

Another source of similar material is the Kirk open-cut. A short tunnel runs from the Kirk shaft to the Colorada ore bins. Cuts were started at both portals and the broken rock was pulled through chutes in the tunnel. As the cuts advanced, chutes were put in ahead of them at 10-foot intervals and staggered on opposite sides of the drift. The rock is limestone already heavily shattered, so that it breaks finely. The maximum overburden is about 75 feet. Nine or ten men work here on day shift only, and supply about 310 tons of waste per day to the chutes. This costs about 13 cents per ton.

About half of the waste, or approximately 500 tons per day, comes from the 5-10 glory hole. This is on the hillside above the fan house at the portal of 5-10 adit. Two vertical raises, 70 feet apart, have been put up from the adit to a sublevel 50 feet above, offset there, and continued to the surface They were driven as stulled raises, the first of which was 100 feet and the second 150 feet in height above the sublevel. After holing through, they were enlarged to about 10 by 10 feet in section above the sublevel to allow large bowlders to pass through, and to 8 by 12 below the sublevel for pocket capacity. Grizzlies were installed on the sublevel (fig. 20). The raises were next belled out at the top, and glory-holing started. Ten-foot down holes are drilled with jackhammers and blasted with 40 per cent gelatin. Most of the rock is thrown into the raise by the blast, but some which is broken but not displaced is barre down by hand. The men wear safety belts when working in the pit. Work is carried on here on day shift only. The crew consists of a jigger boss and 10 to 20 men, four of whom work part of the time in the bulldozing chambers. The rock, a diorite porphyry, is hard and breaks coarsely, so that probably a quarter of it has to be broken on the grizzlies. This is done with hammers, pavement breakers or by plugging and blasting. During one month this glory hole produced waste at an estimated cost of $0.0983 per ton, delivered to the chutes in 5-10 drift.

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The labor amounts to 0.229 man hours per ton (34.9 tons per man-shift) and the powder consumption is 0.12 pound per ton.

Caving. - The major part of the Capote ore body between the 700 and the 1,500 levels has been mined by various caving methods. By 1916 the ground above the 700 level had been worked out by square-setting, shrinkage, and top-slicing, and had been caved to the surface. From 1916 to 1923 considerable areas between the 700 and 1,000 levels were caved by a shrinkage stope and pillar method. Shrinkage stopes 8 feet wide separated by 12-foot pillars were laid out over the entire area to be mined. Starting from pony sets over the tramming drifts, the stopes were split to leave pillars over the drifts and then were carried up vertically for 50 or 60 feet. Sometimes they were mined to the level above, and often a long narrow stope was carried up at one or more sides of the ore body to delimit the area caved. As the stopes went up, the pillars between were weakened or entirely broken through, until the ground above began to drop. Stoping then ceased, and the caved ore was drawn out through the chutes and hand-trammed to the shaft. This method was successful in that it caved the ground. However, it required the actual drilling and breaking of a large proportion of the ore in the block and often caused loss of ore or considerable dilution due to the failure of the pillars to break down entirely between the stopes.

In 1924 a section of the ore body between the 800 and 900 levels about 75 feet wide and 150 feet long was mined by undercut caving. A narrow shrinkage stope entirely surrounding the block was carried from the fourth floor of the 900 level to the 800 level, or about 70 feet. The plug of ore thus cut off was undercut on the fourth floor by driving small untimbered drifts across it and blasting out the pillars between. The ore was drawn out through numerous chutes on the 900 level.

The area directly below this was caved in 1925 partly by undercutting with drifts on the third floor and partly by belling out and blasting down rows of raises spaced at 10 or 15 foot intervals along the tramming drifts.

On the 1,300, 1,400, and 1,500 levels the methods of caving have been alike. A fringe drift is driven around the ore body on the level, and tramming drifts at 40-foot centers are driven through from one side to the other. These drifts are timbered with 10 by 10 inch sets spaced 20 inches center to center, often with double caps. Ten-inch blocks are used for collar braces. Chutes are spaced 15 to 20 feet apart and staggered on opposite sides of the drifts. One-compartment raises are carried up from these chutes to the fourth floor, 25 feet above the rail, sometimes vertically and sometimes inclined away from the drifts to reach approximately 20-foot spacing on that floor. On the fourth floor untimbered drifts about 4 by 6 feet in section are driven parallel to the tramming drifts at 20-foot intervals and are connected by others at right angles. In very soft ground alternate subdrifts are omitted to give larger pillars, as the small pillars crush too soon. The tops of the chute raises are belled out and the pillars drilled and blasted, starting at one end of the block and retreating to the other. No boundary shrinkage stopes are necessary. However, at 30-foot vertical intervals small untimbered drifts are run around the edge of the block to create a line of weakness to which the ground will

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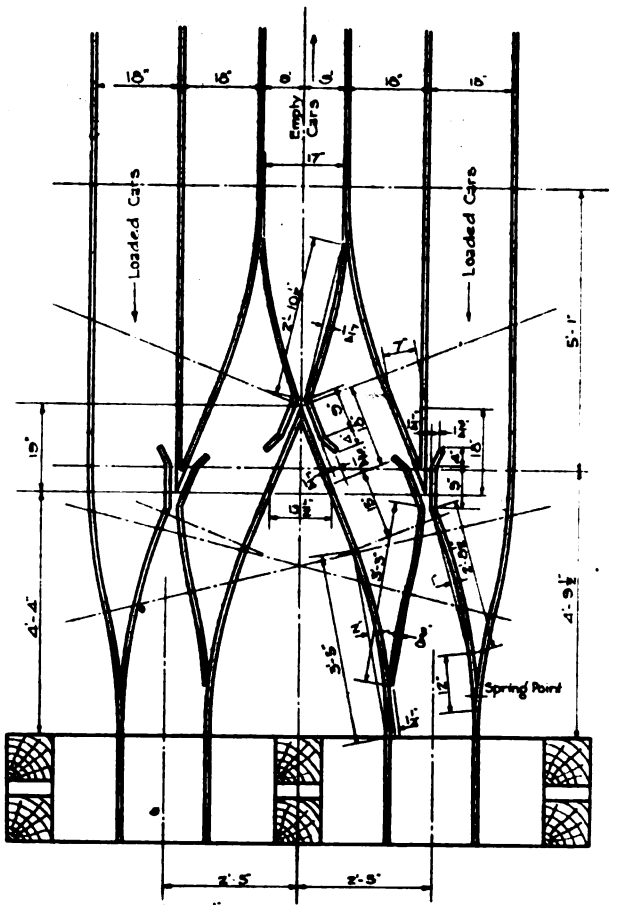

FIGURE 21.
STATION TRACKS
16" GAUGE, 10' RADIUS, 14# RAIL

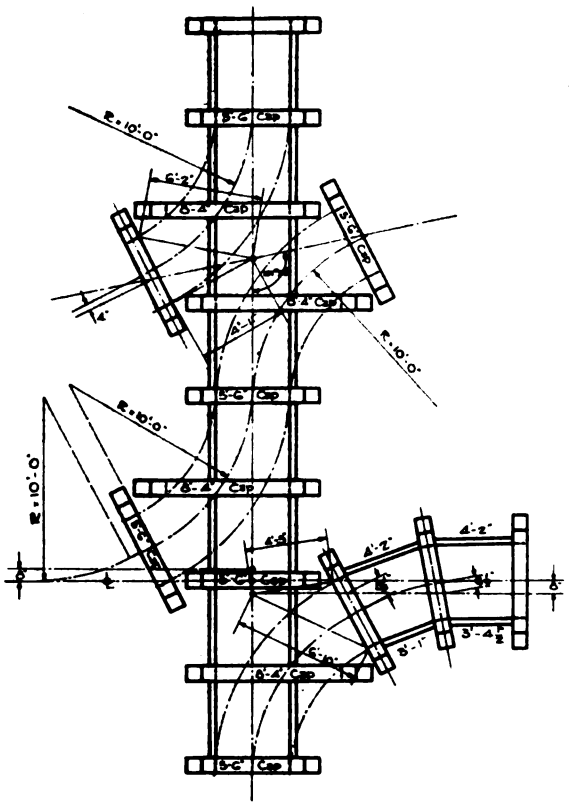

FIGURE 22.
STANDARD TWOWAY TURNOUTS
FOR ONE TON CAR
5'-6" CAPS - 10'-0" RADIUS

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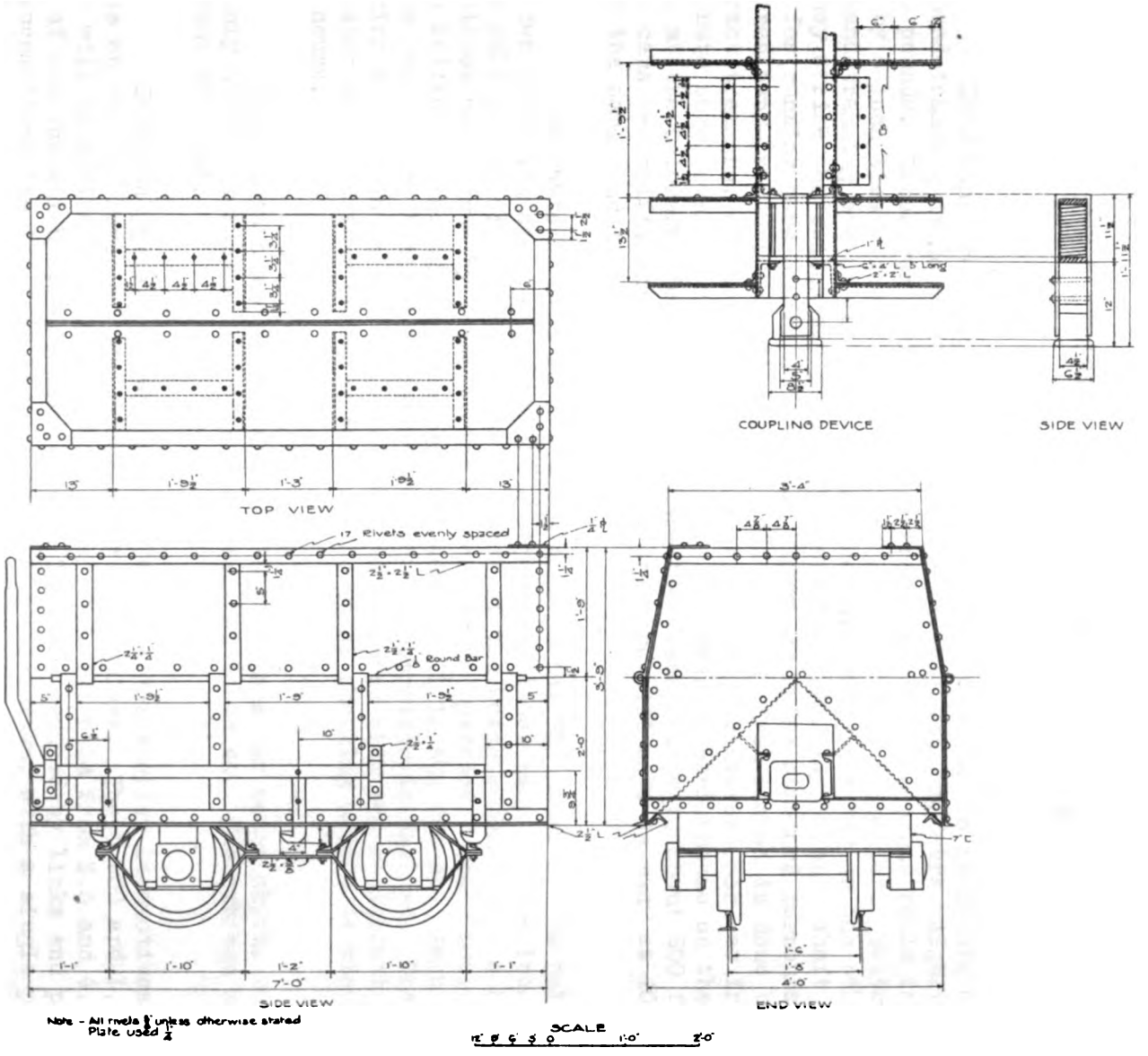

FIGURE 23. - STANDARD 4 TON MINE CAR

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cave and thus reduce dilution from the waste or low-grade walls. Drawing commences from the chutes as soon as the block begins to cave and is continued as uniformly as possible until waste is reached. The ore appears to "pipe" very readily. Consequently, when a chute begins to run waste, another chute is put in close to it and a raise is driven to the broken ground. This chute will frequently produce ore for a considerable length of time. Generally the ore breaks very fine, so that there is little or no blasting in chutes. It is drawn into 1-ton cars which are hand-trammed to the shaft or made into trains for the electric locomotive.

UNDERGROUND TRANSPORTATION

Haulage

Both hand-tramming and motor-haulage are used in the producing mines. All hand-tramming is done with 20-cubic-foot (1-ton) end-dump cars weighing 1,060 pounds. These run on 18-inch gage track made with 16-pound rails laid on 4 by 6 inch ties 4 feet long and spaced 2 feet center to center. Switches for hand-tramming are of the solid type; the cars swing one way or the other as they strike the switches. Figure 21 shows the track layout on a shaft station for running cars on and off cages. Figure 22 shows standard turnouts for timbered hand-tram drifts. Almost all hand-tramming from stopes is done by contract trammers, who are paid a flat rate (20 to 25 centavos) per car from any chute on a level to the shaft station. The average performance on the 1,000 level at the Colorada, for instance, where the average tram is about 800 feet, is 25 cars per shift, though a few of the trammers will make as many as 40 under the same conditions.

Some waste haulage is now being done on the 700 level of the Colorada with two 1-1/2-ton storage-battery locomotives and 1-ton cars. These locomotives pull trains of five or six cars. Most of the waste comes from one chute. Six stopes are served by these trains, which may be operated on one, two, or three shifts, depending upon the need for waste fill in the stopes. Each locomotive has a spare battery to permit continuous operation if desired. The charging station is on the 700 level, and is equipped with two 3-kilowatt motor-generator sets and four charging racks. The usual charging period is about four hours.

These motors are now averaging about 65 tons per motor shift, but commonly handle as much as 100 tons when required to do so. The average haul is about 400 feet.

Four-ton gable-bottomed cars hauled by 4-ton trolley locomotives are in use on the 800 level of the Colorada for ore haulage. The 1,000 and 1,200 level will be similarly equipped. The cars (fig. 23) hold from 3.5 and 4.0 tons of ore and weigh 4,240 pounds empty. They are coupled by links and pins. The locomotives are the reel type of gathering locomotive, with a single pole trolley mounted on the side and one end control.

Because of the shape of the ore body on the 800 level, loop haulage could not be used without unwarranted expense. For this reason a reel locomotive was decided upon, as it eliminated the necessity of having a great many

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trolley switches and also the trolley wire in front of chutes. On the 1,000 level, loop haulage with trolley locomotives is used, and chutes are therefore placed on only one side of drifts. In front of chutes a section of the wire is insulated from the line, and the power is carried by a cable.

Permanent track for these haulage levels is usually laid by special track crews. The light track used with 1-ton cars in the preliminary development work is replaced with 30-pound rails laid to 18-inch gage on 6 by 8 inch treated ties 4 feet long and spaced 2 feet center to center. Sometimes these ties are put in during the first development work so that they do not have to be replaced. The rails are bonded with soldered-terminal cable bonds pressed into holes drilled in the web of the rails. When possible grades are set at one-half per cent in favor of the load. Curves have a minimum radius of 35 feet and standard turnout timbering is used. Split switches are used for all motor-haulage turnouts.

Two locomotives on the 800 level haul trains of six to 10 cars from ore passes or stope chutes. The crews consist of a motorman and two helpers. Ordinarily the cars are spotted under the chutes and loaded without uncoupling the locomotive. Figure 8 shows the standard stope chute. The average haul to the shaft is about 800 feet. A man stationed at the shaft pocket assists in unloading the train, samples and tallies the cars, and cleans the grizzly and track. A loop drift around the shaft makes it unnecessary to uncouple the locomotive for the return trip. The cars are pulled slowly over the grizzly and dumped while in motion.

The pocket grizzlies are constructed of 50-pound rails bent down over the 12-inch I-beam girder which supports the track and is bolted at the ends to the concrete top of the pocket. The pocket on the 800 is 10 feet wide and 40 feet long at the top. It is divided into two parts by a 10-inch reinforced concrete wall. One-half is for first class, the other for second, and each has a capacity of about 190 tons of second-class ore.

The 500 level of the Colorada is now entirely equipped with 36-inch gage track. The ore cars in use there were formerly used in the Oversight and the Veta mines, and a few are still in use on the 200 level of the Veta. They are of the bottom-dump type with a level capacity of 135 cubic feet. At the Colorada they average 7.0 tons of ore per car. They are fitted with automatic 3/4-sized railroad-type couplers and spring draft rigging. The trucks have the wheels attached rigidly to the axle, and are mounted in spring-suspended half-crown bearings. The rigid wheels are the cause of excessive wear on the rails around curves, and may be the cause of occasional axle breakage. New equipment about to be applied to these cars consists of trucks with loose wheels and tapered roller bearings.

The locomotive used for ore haulage on the 500 level is a 10-ton, 2-motored, center-control locomotive. Three of these are used on the 500 level, one for ore and two for waste.

The 500-level track is of 30-pound rail laid to 36-inch gage on treated 6 by 8 by 6 foot ties spaced 2 feet center to center. The minimum

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curve radius on this level is 60 feet. Grades are one-half per cent in favor of the load.

The ore comes from a pocket at the shaft. These pockets provide storage for about 200 tons of first-class ore, 650 tons of second-class ore, and 175 tons of waste. The loading chutes are similar to the stope chutes as regards timbering and control gates. They are lined, however, with 1/4-inch steel plate, and are spaced so that two chutes load one car and the next two chutes the next car, eliminating a great deal of spotting. The ore runs freely and no blasting has to be done. Normally 10 to 15 minutes are required to load a train of 12 cars. The ore bins at the surface are of timber construction and have a total capacity of about 300 tons of high-grade and 1,700 tons of mill ore.

The trains are made up of 12 cars, which are never uncoupled. The track over the surface ore bin is laid out in a loop, so that the motor remains at the front end of the train without switching. In the mine the motor has to be uncoupled and changed to the other end for each trip. This is done on a double track under the loading pocket.

The train crew consists of a motorman and one or two helpers. A man is stationed at the loading station and another at the ore bins outside. These men clean the drifts and grizzlies, assist in loading or unloading, and are also the train dispatchers. Telephones are used to obtain the right-of-way for any train or car passing through the main adit. Ore trains are given the preference.

During a recent normal period of five weeks this train hauled over 1,000 tons in one shift. The distance from shaft pocket to ore bins is 3,200 feet, 775 of which is on the surface.

During the same period referred to above, an average of 900 tons of waste per day was hauled to waste raises on the 500 level. This work is done with 4-ton rocker-dump cars and a 10-ton trolley locomotive. The cars are of 70-cubic-foot capacity and weigh 5,300 pounds. The trucks have loose wheels and are mounted in spring-suspended tapered roller bearings. The cars are also equipped with 3/4-sized, automatic, railroad-type couplers and spring draft rigging.

The waste train coming from the Kirk glory hole travels in part over the same line as the ore train; the total distance, however, is about 4,200 feet. Waste from the main glory hole over the 5-10 adit is trammed only about 2,000 feet. At the Kirk the cars are loaded one at a time under ordinary stope chutes. At the 5-10 adit there are two loading stations, one under each bulldozing chamber. Each has two chutes similar to those under the ore pocket at the shaft.

A waste train crew consists of a motorman and two helpers.

The cars are estimated to hold 3-1/2 tons of the Kirk waste. The train pulling from there is usually made up of six to 10 cars and works three 8-hour shifts per day, averaging 50 cars or 175 tons per shift, with sometimes as much as 75 cars per shift. In addition, this train handles 10 to 20 truck-

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loads of timber and other supplies from the Colorada yards to the shaft. The trucks for this service are all-steel platform trucks with decks 4 feet 6 inches wide, 12 feet 0 inches long, and 2 feet 8 inches above the rail. They are equipped with tapered roller bearings.

The rocker-dump cars hold 4 tons of the coarser waste from the 5-10 chutes. The train hauling from there works only on the regular day and night shifts. With a crew of one motorman and two helpers, it hauls an average of 60 cars or 240 tons per shift, and often as many as 100 cars. The train is made up of 10 cars.

Sometimes fine material builds up in the bottom of the rocker-dump cars and also in the small 20-cubic-foot cars. Compressed-air clay diggers are used to clean out this material, and cause much less wear and tear on the car bottoms than results from the use of 8-pound hammers for the same purpose.

Hoisting

When the development of the mine is completed, all ore will be hoisted in skips from the 800, 1,000, and 1,200 haulage levels. Ore from stopes on other levels will be dropped through ore passes to loading chutes on those levels. At present, however, a large proportion is being trammed in 1-ton cars to the shaft and caged to the 450 level.

Two compartments of the shaft are devoted chiefly to this type of hoisting. The cages are three-decked. The upper deck is equipped with a roof and safety dogs, and weighs 4,100 pounds. The two lower decks are alike; each weighs 2,200 pounds, thus making the total weight of the cage 8,500 pounds. The cage holds 27 men, nine to a deck, or three 1-ton cars. It is operated by a double-drum, 72 by 72 inch, electric hoist on the surface. The drums are grooved, holding 2,500 feet of cable in something over two laps. The cable is standard lay 6 by 19 and 1-1/8 inches in diameter. The hoist is driven through herringbone gears by a 400-hp., 2,200-volt, induction motor with a speed of 595 r.p.m. under full load. The hoisting speed is 1,000 feet per minute. The hoist is equipped with a safety device which prevents overspeed or overwinding, and applies the brakes in case of current failure. Another safety measure is a mechanical interlocking of the control levers in such a manner that the clutches can not be thrown out while the brakes are off.

This hoist is now lifting about 475 cars of ore and waste per day, running on three eight-hour shifts, in addition to lowering and hoisting the shift and handling some timber and other supplies.

One-ton cars are hoisted to the 450 level, trammed about 50 feet across the station, and dumped into the pocket for the motor haulage. Regular lever-operated landing chairs were installed in the shaft, but these have been abandoned in favor of a device consisting chiefly of three heavy links of chain. The links are attached by an eye-bolt and nut to a heavy bracket fastened permanently to a shaft post near the edge of the shaft and about 3 feet above the station floor. The cage is fitted with a heavy solid hook near the floor on one corner post. As the cage is lowered slowly to the station level,

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the cager swings the chain toward the shaft so that the lower link engages the hook on the cage, which then comes to a stop at exactly the right position for unloading the car. When the cage is hoisted, the chain disengages itself automatically and swings into the clear. When hoisting from that level is finished for the time, the cager disconnects the chain and takes it to the next level. This is simpler and just as quick to operate as the old-fashioned chairs, and eliminates repairs and possible shaft accidents.

The hoisting crew for each shift consists of a hoist engineer and an oiler and two cage tenders. In addition, four men work on the 450 station tramming to the pocket.

Skip-hoisting is done with a hoist identical with that operating the large cages. Power and hoisting speed are the same.

The skip-loading devices on the 800 and 100 levels consist of two measuring hoppers and two storage hoppers. Air-operated, down-dropping, vertical steel gates allow ore to run into the measuring hoppers, one below the mill ore chute and one below the high-grade chute. Under the hoppers is a tilting slide which can be thrown to divert the ore from one side to the other. Below the slide are two storage hoppers, one for either compartment. The ore remains in these until the skips are spotted, and then other vertical-sliding air-controlled gates are raised, allowing the ore to drop into the skips. These lower hoppers were put in partly to prevent the spillage and wear on the skips which would be caused by dropping the ore the considerable distance from the upper chutes and over the slide to the skip, and partly because loading can be done more promptly and rapidly. Only about five seconds is needed to load a skip.

The skip is a standard for all the shafts in the district. It is 4 feet by 2 feet 10 inches inside, 6 feet 4 inches deep at the front, and 7 feet at the back. Its level-full capacity is 76 cubic feet, but only 60 cubic feet is used in practice to eliminate any spillage due to slight overloading at the pocket or to the shock which the skip receives upon entering the dumping cradle. The skip is equipped with the usual eccentric, toothed-cam, safety dogs. Its weight is 4,600 pounds, and the usual load is 3.5 tons of ore. The skip dumps about 130 feet above the 500 level into an inclined steel chute 2 feet 6 inches by 3 feet 6 inches in section and made of 1/4-inch plate. This chute drops on a 45° pitch to a point directly over the motor-haulage pockets. There the ore is thrown to either the first or second class pocket by means of a diverting gate. The floor of the chute is lined with old rail, and just above the diverting gate the ore hits a swinging curtain made of old rail, which checks its speed.

The crew on the skip hoist on each of three shifts consists of a hoist engineer, an oiler, and two skip tenders. The average hoisting duty now is about 350 skips per shift, though often as many as 450 have been hoisted in one shift.

A double-drum, double-geared electric hoist is used for the dinkey cage in the Colorada shaft, the cages in the ventilation shaft, and several

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other installations in the camp. The drums are 42 inches in diameter and 30 inches wide and are grooved for 3/4-inch rope. The motor is 112 horsepower and the hoisting speed is 495 feet per minute. As manufactured it was equipped with band brakes, but in several cases these have been replaced by post brakes. Brake shoes are cut from 1-inch boiler plate and fitted with angle irons to which the brake band is attached. Asbestos brake blocks are giving excellent service in place of the basswood formerly used. This hoist is very satisfactory to depths of 500 to 600 feet and is often used for considerably greater depths.

COMPRESSED-AIR SUPPLY

The present supply of compressed air for the camp comes from three sources. A large steam-driven compressor at the smelter at Ronquillo and electric-driven machines at the Sierra de Cobre and Colorada are all connected to the same lines.

The Ronquillo compressor, with a capacity of approximately 4,500 cubic feet per minute, is connected to the mines by a 10 and 12 inch pipe line as far as the Veta Grande, and thence to the Colorada by a 6-inch line. The latter section is known to be the cause of a serious pressure drop and is to be replaced by larger pipe.

On the surface at the Colorada shaft is a twin angle-compound direct-connected compressor, 22 by 13 by 14 inches, driven at 225 r.p.m. by a 2,300-volt, 450-hp., synchronous motor. Its capacity is 2,200 cubic feet per minute.

At the old Sierra de Cobre are two horizontal duplex compressors. One is 17-1/2 by 29 by 21 inches driven at 180 r.p.m. by a direct-connected, 422-hp., 2,200-volt, synchronous motor. Its capacity is 2,874 cubic feet per minute. The other machine is of the same make and type but with cylinders 16-1/4 by 28-1/2 by 24 inches, driven at 180 r.p.m. by a 350-hp. induction motor. It has a capacity of 2,430 cubic feet per minute.

The Colorada alone is now using approximately 6,000 cubic feet per minute for about 75 drills and 10 scraper hoists in actual daily operation. Air is delivered to these machines at an average pressure of 85 pounds per square inch.

PUMPING

No large amounts of water are contended with in any of the mines. The Capote is now pumping 1,100,000 to 1,200,000 gallons per day, or 750 to 850 gallons per minute. Practically all of this is collected on the 1,600 level and pumped to the 1,200 level, from which it is relayed to the surface. In the 1,600 pump station there are three two-stage horizontal centrifugals, 6 by 5 inches, driven at 1,760 r.p.m. by 150-hp. motors. Their rated capacity at 500-foot head is 500 gallons per minute. The actual head is about 410 feet. On the 1,200 level there are three 5-1/2 by 12 inch triplex pumps with capacities of 370 gallons per minute at 60 r.p.m. They are driven by 125-hp. motors. A fourth pump on this level is a 6-1/2 by 14-inch triplex pump driven by a 150-hp. motor. This unit has a capacity of 300 gallons per minute at 52 r.p.m. The head on the 1,200 level pumps is 1,100 feet.

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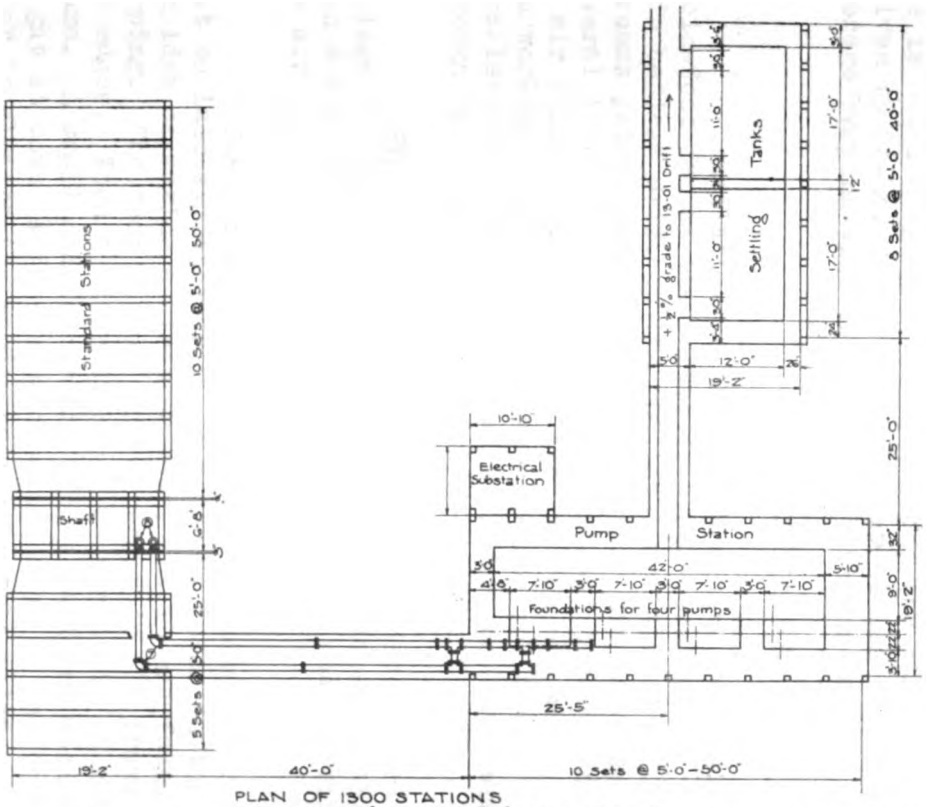
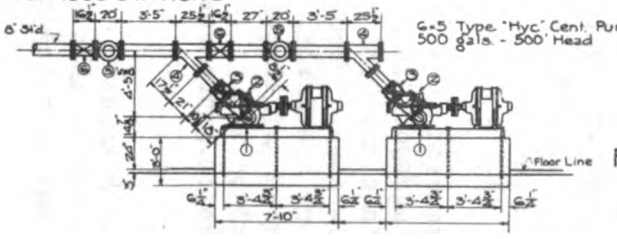
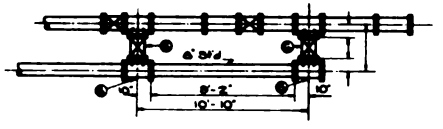


PLAN OF 1300 STATIONS



1. 5"x6" Elbow Reducer
2. 6" Check Valve
3. 6" Gate Valve
4. 8"x8"x6" Lateral
6. 8" Gate valve
5. 8"x8"x8" Tee
7. 8" L. R. Elbow
8. 8" Sq. Base L. R. Elbow
9. 6" L. R. Elbow
10. 6" Foot Valve

All fittings flanged C.I

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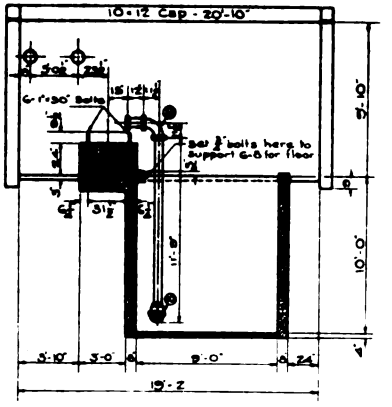
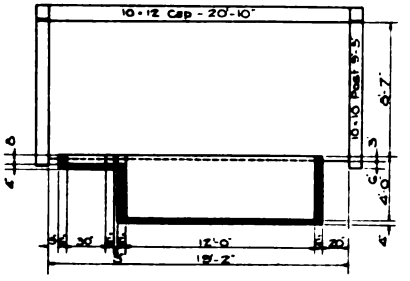


SECTION THROUGH PUMP STATION



SECTION THROUGH SETTLING TANKS

FIGURE 24. – PUMP STATION ON 1300 LEVEL, LA COLORADA MINE

SCALE FEET
0 2 4 6 8 10 12 14 16

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In the Colorada mine all the water is pumped from the 1,300 level to the 900 and thence to the 500 levels, where it flows out the main adit to the surface. Figure 24 shows the 1,300-level pump station. Only two units have been installed, but the foundation is ready for a third should it be needed. These pumps are 6 by 5 inch, horizontal centrifugals identical with those on the Capote 1,600 level. Two of the same pumps are installed on the 900 level. The actual head on both the 1,300 and 900 level pumps is 500 feet. The flow of water in the mine has increased steadily during 1929 from 56,000 gallons per day in January to 120,000 (83-1/3 gallons per minute) per day in September partly because of flows of water encountered in a long prospect drift being driven on the 1,300 level. The present flow is handled by one centrifugal pump on the 900 and one on the 1,300 level, which run an average of 4 hours per day. It is the experience of the district that very large temporary flows of water may be struck when least expected, and the mines are therefore equipped to handle much more than the average flow would seem to require.

The Veta Grande is the only mine now operating in which any relation can be traced between the monthly rainfall and the amount of water pumped. Two pumps are handling about 94,000 gallons per day (65 gallons per minute). One is a 5-1/2 by 9 inch triplex, and the other a 6 by 9 inch pump. Both are driven by 25-hp. motors and have capacities of 175 gallons per minute. The average pumping time is about 10 hours per day for one pump.

VENTILATION

Ventilation of the Colorada mine is provided by a reversible 70,000-cubic-foot fan at the portal of a 500-level adit. The air intakes through the main haulage drift on the 500 level and also down the Colorada shaft, the two streams joining at the shaft station. Air from the shaft passes across the several levels by way of the haulage and development drifts and upcasts in an air raise on the opposite side of the ore body. Regulating doors between the working areas and the air raise control the amount of air coming off on each level and create a pressure difference that causes circulation upward through the stopes from level to level.

Figure 25 shows the air-operated ventilation door used on motor-haulage levels. The control levers are placed at the side of the drift, more than a train's length away from the door, and are connected to the valve of the air cylinder by 1/4-inch wire rope.

The three thicknesses of board make a strong and tight door, but must be laid symmetrically. A diagonal layer in the center was tried, with the idea of making a stronger door, but it was found that this caused decided warping. The door closes into a recess in the frame to reduce leakage around the edges. When a water ditch is required, it is concreted under the door frame. A small canvas curtain with a strip of wood at the lower edge to weight it down is then hung from the door to the bottom of the ditch. When water is flowing the wood floats but still holds the canvas to the surface of the water, thus preventing air leakage.

The clear area of the Colorada shaft is 100 square feet, exclusive of the manway compartment. The 500-level haulage adit, which is a main

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intake, is at least 8 by 8 feet in section, and is generally larger. Drifts on other levels are at least 6 by 8 feet in the clear, whether timbered or untimbered. The air raise has three compartments 5-1/2 by 6 feet inside, two of which are used as hoisting compartments; the third is a manway with landings at every 16 feet. A tunnel 8 by 8 feet in the clear, untimbered, leads from the top of the air raise to the fan. As shown in Figure 4, the ventilation system is not complete to the 1,300 level; the 1,000 level is the lowest now connected to the air raise. Development raises serve to ventilate the lower levels until the air raise is finished.

ACCIDENT PREVENTION, FIRST-AID, AND MINE-RESCUE TRAINING

Safety First work at Cananea is in charge of a Safety-First director. After daily trips through the mines and plant, he makes written reports to the mine superintendent on the condition of each working place as regards safety. The existence of fire hazards and the condition of manways, ore passes, grizzlies, shaft stations, drift timber, powder magazines, and machinery are among the items noted in these reports. Falls of rock are the greatest accident hazard at present, and emphasis is laid upon barring down before starting work. All machinery is fitted with safety guards. Small hinged grizzlies cover the tops of all timber slides. Men working where serious falls might occur are required to wear safety belts. Goggles are worn when breaking rock with hammers or moils. Hard-boiled hats are compulsory for all persons going underground. As an added incentive, jigger bosses whose crews work 1,000 man-shifts without a time-lost accident are paid a bonus.

Another phase of the safety director's work is the training of men in first aid. Special attention is paid to the stopping of arterial bleeding and the use of artificial respiration. The course consists of eight or 10 lessons. The classes are held outside working hours, but with extra compensation for the men who attend. All bosses in the mine carry first-aid kits and are competent to use them, and several hundred men have likewise been given the first-aid course.

The ores being mined at present are generally low in sulphide, so that no fire hazard exists from heating and burning of the ore. However, considerable attention is paid to the prevention and combating of possible fires from other sources. All of the permanent timbering is now done with treated timber, which is fire-resisting. The shaft was sunk before the treating plant was in operation, however, and only the skip compartments, added at a later date, have treated timber. The shaft is therefore protected in other ways. A line of sprays is installed in it at 25-foot vertical intervals. These are turned on at intervals to keep the timber permanently wet. For flooding the shaft in case of fire, one water line at the collar can deliver 300 gallons per minute and another at the 500 level can contribute the same amount. These are fed from two storage tanks on the surface. Above each station a 10-inch ring of concrete has been poured around the shaft and extends from the rock to the outside of one set. The concrete will prevent a fire from working upward back of the wet lagging and will also bring in water which may be running down the walls. Fire hydrants and hose, as well as chemical extinguishers, are installed on each shaft station. These are tested periodically.

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The shaft can be completely cut off from the mine workings by means of steel fire doors near it on every level. These can all be closed at once by opening an air valve at the surface or at the 500, 800, or 1,000 level stations. In case of fire in the shaft, the doors would be closed and the fan would be reversed, thus putting the shaft under pressure and keeping the smoke and gas out of the mine. Men could then escape by way of the air raise and ventilation tunnel on the 500 level.

Junction boxes and electric switches on the shaft stations are enclosed in concrete boxes. Inflammable waste material is not allowed to accumulate in the mine. Each electric locomotive carries a small extinguisher. If fire occurs, ethyl mercaptan can be put in the air lines to warn men to come out of the mine. Finally, about 40 men have been given training in mine-rescue work and the use of oxygen breathing apparatus.

WAGE, CONTRACT, AND BONUS SYSTEMS

Between 50 and 60 per cent of the whole underground force is employed on a contract basis. Practically all raising and the larger part of drifting are done on contract. Some timbering of drifts, practically all tramming, and a large part of the stoping are contracted for. All men thus employed are contractors in relation to the company and share equally in the contract payment.

Development work is contracted at so much per foot of advance, timbering per set, tramming per car or per ton, and stoping per cubic meter. The company furnishes everything except labor and explosives. Contracts are generally made out for no specified amount of work and are paid off and renewed each half-month. Even when contracts are given for definite amounts of work, requiring more than two weeks to finish, full payment is made after each period for all work completed, and nothing is held back pending completion of the work. Informal bonuses are often paid for difficult work, such as completing the last of a long raise.

ADMINISTRATIVE ORGANIZATION

Under the general mine foreman are four or five mine foremen, one at each operating mine. On night shift each mine is in charge of an assistant or night foreman. Next in authority are the American shift bosses, up to five or six on a shift at each mine. These men are assigned to definite parts of the mines and are in charge of all operations within their territories, without regard to kind of work. They are each assisted by from one to five Mexican jigger bosses who are directly in charge of the men. Each jigger boss likewise covers a definite territory, such as two or three stopes, or a number of development headings. Their crews range from 10 to 40 men, averaging about 25.

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Table 4. - Summary of costs, Colorada mine, first six months of 1929 1/

Tons of ore produced during the period: 262,278

	Tons
Rill cut and fill	104,057
Horizontal cut and fill	37,949
Square-set	32,220
Shrinkage	36,354
Drifting	51,698
	262,278

	Underground costs per ton of ore produced							
	Labor	Super-vision	Comp. air, drills, and steel	Power	Explo-sives	Timber	Other sup-plies	Total
Development:								
Drifting and raising; In ore and in rock	.2260	.0396	.0540	.0151	.0640	.0591	.1032	.5610
Mining	.3748	.1316	.1808	.0071	.2146	.1979	.0966	1.2034
Transportation	.1126	-	-	.0250	-	-	.0288	.1664
General underground	.2115	-	-	.0120	-	-	.0541	.2776
Surface expense	.1767	-	-	.0107	-	-	.0452	.2326
Totals	1.1016	.1712	.2348	.0699	.2786	.2570	.3279	2.4410

1/ These costs exclude mine departmental expense, which includes superintendence, engineering, sampling, watchmen, time office, etc.

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Table 5. - Summary of costs, Capote mine, first six months of 1929 1/

Tons of ore hoisted during the period: 142,168

Mining method: Undercut caving, top slice, and cut and fill

	Underground costs per ton of ore hoisted							
	Labor	Super-vision	Comp. air, drills, and steel	Power	Explo-sives	Timber	Other sup-plies	Total
Development:								
Drifting and raising: In ore and in rock	.0196	-	.0018	.0111	.0094	.0068	.0100	.0577
Mining	.2623	.1188	.1023	.0200	.0995	.1725	.1187	.8941
Transportation	.0187	-	.0001	.1416	-	.0007	.0404	.2015
General underground	.0316	-	-	.0100	-	-	.0412	.0828
Surface expense	.1925	.0135	.0071	.0110	-	.0017	.0163	.2421
Totals	.5247	.1323	.1113	.1937	.1079	.1817	.2266	1.4782

1/ These costs exclude mine departmental expense, which includes superintendence, engineering, sampling, watchmen, time office, etc.

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Table 6. - Summary of costs, Veta Grande mine, first six months of 1929 1/

Tons of ore hoisted during the period: 42,565

Mining method: Square set, top slice, and cut and fill

	Underground costs per ton of ore hoisted							
	Labor	Super-vision	Com. air, drills, and steel	Power	Explo-sives	Timber	Other sup-plies	Total
Development:								
Drifting and raising:								
In ore and in rock	.1587	.0194	.0230	.0097	.0258	.0648	.0212	.3226
Mining	.6377	.0941	.1323	.0283	.1498	.3524	.1341	1.5287
Transportation	.0741	-	.0012	.0095	-	.0111	.0119	.1078
General underground ...	.0468	.0182	.0001	.0177	-	-	.0393	.1221
Surface expense	.0900	-	-	.0010	-	.0125	.0118	.1153
Totals	1.0075	.1317	.1566	.0662	.1756	.4408	.2183	2.1965

1/ These costs exclude mine departmental expense, which includes superintendence, engineering, sampling, watchmen, time office, etc.

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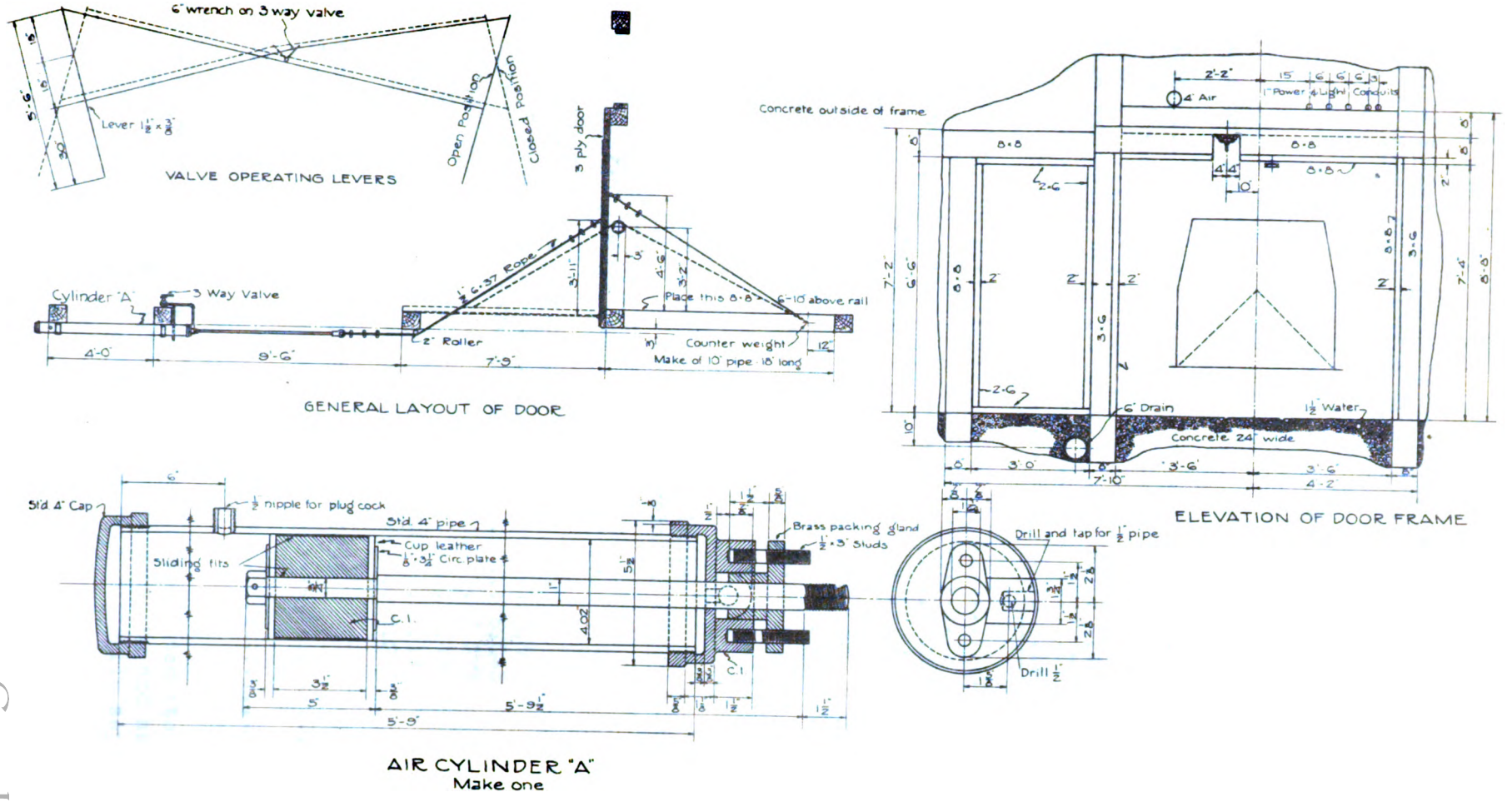

FIGURE 25. – VENTILATION DOOR FOR MOTOR HAULAGE DRIFTS

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Table 7. - Summary of costs in units of labor, power, and supplies, Colorado mine, first half of 1929

Tons of ore hoisted: 262,278

A. Labor (man hours per ton):

Breaking	.876	
Timbering	.729	
Mucking	.990	
Haulage and hoisting	.494	
Supervision	.297	
General	.163	
Total underground		3.619
Tons per man-shift underground		2.21
Surface labor, directly chargeable	.531	
distributed charge	.209	
Total surface		.740
Tons per man-shift on surface		10.81
Tons per man-shift, total labor		1.835
Labor, per cent of total cost		52.10

B. Power and Supplies:

Explosives (lbs. per ton, 85% of 40% gelatin 15% of 60% gelatin)		1.37
Timber, bd. ft. per ton		7.19
Total electric power, kw.h. per ton		11.291
Motor haulage	0.986	
Air compression (part of air only)	6.045	
Hoisting	3.373	
Pumping	0.454	
Ventilation	0.195	
General underground	0.238	
Other supplies in per cent of total supplies and power		30.01
Supplies and power, per cent of total cost		42.16

Note: 5.74 per cent of total cost is for several distributed items such as shop overhead, narrow-gage railroad, and sampling and assaying, in which labor and supplies could not be satisfactorily separated.

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